1960 ANNUAL REPORT

Textile Research Institute

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PRINCETON, NEW JERSEY

Message from the Chairman

In completing my second term as Chairman of the Board of Textile Research Institute, it is gratifying to report another year of successful operation. Prosecution of the Institute's principal functions—basic research, graduate training of scientists, and diffusion of knowledge—has continued with satisfactory progress evident in all three categories. At the same time, we operated with increased total income and it seems significant that membership income and fellowship grants were at all-time highs in 1960. By virtue of tight budgetary control and adherence to sound fiscal policies developed by the Board, there was an excess of income over expense of $12,664. It will be interesting to present and past Trustees to learn that a major contribution to this welcome black figure was made by the TRI Publications Department. Considering that we also assumed an additional cost burden of $16,000, representing the new staff pension plan, which went into effect on January 1, the over-all fiscal performance was reasonably good in 1960. The new staff pension plan will contribute significantly to the efforts of the Board for continuous long-range growth in activity.

A major staff reorganization took place in 1960, necessitated by the resignation of Dr. White, Director of Research. Upon the recommendation of our President, Dr. Dillon, four senior scientists, Messrs. J. H. Dusenbury, W. J. Lyons, L. Rebenfeld, and R. F. Schwenker, Jr. were designated as Associate Research Directors. They have been responsible for the research program, reporting directly to Dr. Dillon. Judging by the results, this was

WILLIAM E. CLARK

a sound move. They are to be complimented, as are Dr. Toner, Director of Publications, and Mr. Alford, Secretary-Treasurer, for the significant roles which they have occupied in TRI's 1960 operation. Despite the extra pressure on his time, our President, Dr. Dillon, continued to maintain his calm, sure-footed, and sometimes uncanny ability for solving problems created by the Board, the Staff, and the members.

It is impossible in a brief report to recount the contributions of the Institute Trustees, whose enthusiasm and willingness to serve whenever called upon has been a delight and inspiration. The Executive Committee, under the Chairmanship of Russell W. Peterson, has been most effective, as has been the Committee on Long-Range Planning, guided by Levon M. Yacubian. The Committee on Education, chaired by M. E. Campbell, suggested certain changes in our fellowship program which were adopted by the Board and which have evidently been most constructive. Dr. Norman C. Armitage, Chairman of the General Research Advisory Committee, has inaugurated a system of preprint-summaries of presentations to be made at the meetings which should greatly aid the Committee in its guidance of our research program.

There is no question that TRI has progressed in a very encouraging manner within the past few years and certainly the year 1960 gives reason for optimism. Yet we must recognize that the textile industry and its allied branches have serious problems which will not be solved overnight. TRI

will probably always feel the effects of fluctuating business conditions. Yet it is obvious that an organization such as TRI must have continuity of staff and program if it is to contribute properly to the long-range betterment of the industries which it is dedicated to serve. The development of this stability in TRI will continue to be a major objective of the officers and staff of your organization.

As my two years of office as Chairman of the Board of TRI come to a close, I want to express my feeling of deep pleasure and pride in having been so honored. Never have I had the privilege of working so closely with a more capable and dedicated group of men.

Cordially,

William E. Clark

WILLIAM E. CLARK
Chairman of the Board

Officers and Trustees at Board of Trustees meeting on March 23, 1960. From left to right, first line, Messrs. Lawrence, Hotte, Bissinger, Clark, Peterson, Dillon, Allen, Goldberg, Cone; second line, Alford, Smith, Baum, Kropf, Dexter, Grace, Hedberg, Spears; third line, Harris, Yacubian, Hanlon, Masland, Harmon, Jones, Hamburger, McLeod.

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Report of the President—1960

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JOHN H. DILLON

Report of the President—1960

Mr. William E. Clark, in his *Message from the Chairman,* has summarized very concisely TRI activities during the past year and has given a clear picture of TRI's situation at the close of 1960. In this Report of the President, the points discussed by Mr. Clark will be covered in more detail and a brief account of our activities will be given, organized according to the Institute's prime objectives: (1) conduct of long-range basic research, (2) training of scientists at the graduate level, and (3) dissemination of research information.

TRI RESEARCH

General Program

The General Research Program is truly the core of the Institute's research effort. Thus, it was encouraging to find that the support for it increased considerably in 1960 by virtue of higher income from membership dues and fellowship grants. The program consists mainly of the basic research assignments of Predoctoral, Postdoctoral, and Visiting Fellows. A list of

these assignments is given in the Appendix to this report. It is hoped that support of the General Program will continue to grow so that the work of full-time scientists can be included to a larger extent than is currently possible.

Sponsored Projects

Sponsored project programs constituted about three-fourths of the total TRI research effort in 1960. It is felt that we have been successful in keeping these project programs within the framework of basic, long-range research. This should be evident from an inspection of the project titles and objectives listed in the Appendix. It should be noted also that TRI accepts project assignments, whether they be sponsored by member groups, individual member companies, or government agencies, only on the condition that significant findings be freely publishable in the scientific literature.

One new group project, entitled Fiber Surface Studies, was initiated in 1960. The project supported by the International Wool Secretariat was terminated on October 1, but it should be noted that IWS joined the group project on Permanent Set and Supercontraction of Keratin Fibers.

Research Staff

The steadily increasing demand for research scientists was accelerated in 1960. This was quite apparent as our young Ph.D. graduates entered industrial positions with starting salaries alarmingly close to those of senior scientists of established reputations based on 7 to 10 years of research experience at TRI. We thus found ourselves in a very difficult situation, both as regards recruitment of young scientists and retention of senior scientists. These conditions exist in many academic institutions and indeed the problem of acquiring and keeping scientists is hectic in industry, where limitations upon salaries are not as strict. In any event, TRI felt these pressures in 1960 and will continue to feel them.

Discussions concerning Dr. White's decision to resign had taken place over an extended period. Thus we were well prepared to continue research operations under our four able Associate Research Directors, Messrs. Dusenbury, Lyons, Rebenfeld, and Schwenker, with the President reassuming overall direction of the program. He has been very pleased indeed with their performance.

In addition to his research responsibilities, Dr. Rebenfeld was placed in administrative charge of the Educational Program on January 1, 1960. He entered into his assignment as Educational Program Director with vigor and enthusiasm which are reflected in the current healthy state of the educational effort.

There was a normal amount of turnover in the technician grades and one senior scientist, Dr. Walter Lobunez, left us in 1960. It is good to report, however, that Mr. Stanley Scheier joined our staff as senior scientist of the new group project on Fiber Surface Studies. He earned his M.S. degree under Professor Backer at M.I.T. and has had textile research experience in industry and at the Swedish Textile Research Institute in Göteborg. Also very encouraging is the fact that three very able scientists have joined the staff as Research Associates: Sir Hugh Taylor, Dean Emeritus of the Princeton Graduate School and for many years chairman of the Chemistry Department; Professor Arthur V. Tobolsky of Princeton University, internationally known polymer chemist; and Dr. Donald H. Powers, Vice-President of Warner-Lambert Pharmaceutical Company and well known for his pioneering work in the field of textile chemical finishing. It is thus evident that the scientific quality of the TRI staff is being maintained although certain difficulties in filling full-time scientist positions are being experienced.

General Research Advisory Committee

The General Research Advisory Committee met on June 6, 1960, with an excellent attendance (see the Appendix for a complete list of committee members). In accord with a suggestion made by Dr. Norman C. Armitage, Chairman of the Committee, summaries of the various staff presentations had been furnished to committee members in advance of the meeting date. This practice apparently served very well to facilitate the discussions and will be followed in the future.

After a summary by Dr. Dillon of the Institute's available research funds and staff assignments, the following technical papers were given by TRI staff and Fellows:

Volume Changes which Accompany Acid-Base Reactions of Protein Fibers by D. D. Kasarda, U. S. Rubber Company Foundation Fellow

Mass Transfer Between Phases by T. J. Cochrane, Courtaulds Fellow

TRI Research on Cotton by Ludwig Rebenfeld, Associate Research Director

Fiber Surface Studies by W. J. Lyons, Associate Research Director
High Temperature Properties of Fibrous Polymers by Robert F. Schwenker, Jr., Associate Research Director

All of these topics were discussed by the Committee. It was decided that a group project on *Fiber Surface Studies* should be developed, in line with the program suggested by Dr. Lyons, and that work of the type described by Mr. Schwenker should be incorporated in the General Program.

Research Results

In previous Annual Reports, attempts have been made to describe Institute research results within a rather rigid framework of arbitrary categories and to indicate the participating scientists and the sponsorship of each assignment. On the premise that what really matters to the reader is the actual basis and the results of the research, a quite different approach is used in this report. The categories have been chosen so as to describe the principal phases of the program, as they actually exist. This would appear more realistic than the former practice of adhering to a set of predetermined topics related to possible textile application. Sponsorship and the names of research personnel participating in each assignment, whether they be staff members or graduate students, are omitted; complete information of this type can be gleaned from the Appendix. Thus the categories under which the 1960 TRI research program is described are: Structure and Chemistry of Cellulose, Studies of Keratin Fibers, Synthetic Fibrous Polymers, Thermal Behavior of Textile Materials, Physics of Fibers, Properties of Fiber Assemblies, and Chemical Treatments of Cotton.

Structure and Chemistry of Cellulose

In keeping with the dominant position occupied by cellulose among fiber-forming materials and with current interest in improving the properties of cellulosic fibers, a considerable portion of the TRI program involves the chemical modification of cellulose. Although cellulose as a polyhydric alcohol should be very reactive, readily forming esters and ethers, it is in fact relatively unreactive. However, the reactivity of cellulose may be enhanced by forming highly reactive intermediates or by increasing the number of hydroxyl groups available for reaction; these approaches are being explored.

Sodio Cellulose Derivatives: Alkali metal derivatives of cellulose, such as sodium cellulosates, would seem to offer considerable promise as reactive intermediates for the preparation of various cellulose esters and ethers. Such derivatives are distinguished from alkali cellulose in that no water or sodium hydroxide is present but a true sodio derivative, R_{cell}-ONa, obtains. Sodio derivatives of cotton and viscose rayon have been obtained by an exchange reaction between the cellulose and sodium alkoxides, such as sodium butoxide, in equilibrium mixtures of the sodium alkoxide in the corresponding alcohol. Derivatives of degree of substitution ranging from 0.5 to 1.7 were obtained in this way. In order to gain information as to the reactivity of the sodium cellulosates as well as to the distribution of the substituent sodium in the products, the condensation of the sodium cellulosates with methyl iodide to form methyl celluloses has been studied. The distribution of the sodium substituent has been determined from the distributions found for methoxyl groups in the methylated derivatives. Methylated products were subjected to acid hydrolysis down to the monomer stage and the neutralized hydrolyzates analyzed by quantitative paper chromatography. Glucose, monomethyl glucose, dimethyl glucose, and trimethyl glucose constituted the products of hydrolysis. The monomethyl glucose fraction was further separated to disclose the presence of the 2, 3, and 6 isomers. The distribution data obtained indicated that sodium was substituted in a nearly random manner. Analysis of the monomethyl glucose fractions showed preferential substitution at carbons 6 and 2.

Similar derivatives have been prepared, in the course of a research project on the resilience of cotton, by the reaction of sodium isoamylate in xylene with cellulose as well as by the reaction of sodium in liquid ammonia with cellulose. The reactions of the sodium cellulosates with methylene dibromide to obtain cross-linked products were studied. Data obtained on the relative rates of reaction of methylene dibromide with alkali cellulose and sodium cellulosate indicate a much faster rate of reaction for the sodium cellulosate.

Non-Aqueous Swelling Agents for Cotton Cellulose: A project on the investigation of non-aqueous swelling agents for cotton has been initiated. The object is to provide means for obtaining new chemical and physical modifications of cotton. Reactions with cotton cellulose must necessarily be heterogeneous due to the relative insolubility of cellulose and the fact that cellulose structure is characterized by substantial crystalline regions and by hydrogen bonding of hydroxyl groups in the non-crystalline or amorphous portions, as well as in the crystalline portions. As a result, only a fraction of the total number of hydroxyl groups present in cellulose is available for reaction. To overcome these limitations and to increase the number of hydroxyl groups available for reaction, the cellulose structure is commonly opened up by pretreatment with swelling agents.

These agents are almost exclusively aqueous solutions of acids, bases, and salts. However, many desirable chemical modifications of cellulose cannot be achieved efficiently, and some not at all, because the reagents required are water sensitive or unstable in water. To compound the problem, the non-aqueous media with which these same reagents are compatible are, in general, not good swelling agents.

The effect of single- and multi-component organic solvent systems as swelling agents is being studied in order to elucidate the roles of internal pressure, polarity, and molar volume of such systems. The degree of fiber swelling is being evaluated by liquid imbibition measurements whereby the quantity of the swelling agent imbibed is determined by weight increase. The effect of the swelling treatments on cellulose reactivity is being evaluated by the degree of methylation obtainable after methylation of the treated samples by an appropriate method. The mode and locus of action of the swelling agents are being studied via the distribution of the methoxyl groups in methylated samples. The mechanical properties of cotton fibers subjected to the more promising swelling treatments are also being examined.

Homogeneous Methylation of Cellulose Acetate: A study has been made of the nature and location of the free hydroxyl groups in acetone-soluble secondary cellulose acetate. Secondary cellulose acetate was homogeneously methylated in dioxane with etherial diazomethane, using boron trifluoride-ether complex as a catalyst for the methylation reaction. The distributions of methoxyl groups in the methylated samples were obtained by acid hydrolysis of the samples and quantitative estimation of the various sugar components by paper-chromatographic techniques. Glucose, monomethyl glucose, and dimethyl glucose were found. The monomethyl glucose fraction was further resolved into its isomers and 2, 3, and 6-O-monomethyl glucose were found to be present. It was thus established that some fraction of the hydroxyl groups located at carbons 2, 3, and 6 is free and available for reaction in secondary cellulose acetate.

6-Thio Derivatives of Cellulose and D-Glucose: In recent years there has been great interest in the effect of cross-linking cellulose chains on the physical properties of cellulosic fibers and fabrics, particularly with respect to achievement of crease recovery. Wool derives many desirable physical properties from the presence of disulfide cross-links, and previous work at TRI on the chemical modification of cotton has indicated a reaction sequence for cross-linking cellulose in this way. This investigation is a study of the fundamental reactions involved in the introduction of disulfide cross-links into cellulose. The reactions have been studied on glucose and methyl glucopyranosides as model compounds. Crystalline tosyl esters of the starting compounds were prepared and the tosyloxy groups at the carbon 6 positions were replaced with thiolacetate groups by

reaction with potassium thiolacetate. Hydrolysis of these products gave a series of thiol sugars, and oxidation of the derivatives with buffered iodine solution readily produced the corresponding disulfide derivatives as crystalline compounds in about 65 percent yield. Alternate synthetic routes to the disulfide were studied, utilizing sodium and potassium thiosulfate and thiocyanate, with satisfactory results. Preliminary studies were made of the application of the preferred reaction sequence involving potassium thiolacetate to cellulose to obtain 6,6-disulfide cross-linked products.

JOSEPH H. DUSENBURY
Associate Research Director

STUDIES OF KERATIN FIBERS

During the past year, studies of keratin fibers have been carried out in three general areas, two of which have involved work related to the currently interesting "minimum care" treatments of wool. One of these studies has been concerned with the effects of chemical treatments on the recovery from deformation of wool fibers and fabrics, and the other, with the permanent set and supercontraction of wool and other keratin fibers. Studies, constituting the third area, were aimed at obtaining a better fundamental understanding of the properties of keratin fibers.

Chemical Treatments of Wool Fibers and Fabrics: In one of the investigations, completed during the year, a study was made of the recovery of wool fibers and fabrics from the types of deformation encountered in the creasing and wrinkling of a fabric and of the effects of chemical treatments, such as internal polymer deposition and cross-linking, were examined. A lightweight worsted fabric, prepared from an Australian Merino wool, was used in the experiments, and dimethylol ethyleneurea (DMEU) was employed in the treatments with

various acid catalysts. This type of treatment would be expected to combine the effects of internal resin deposition and cross-linking and has found considerable application for improving the wrinkle recovery of cotton fabrics. The effects upon wool, however, were found to be much less extensive than has been found with cotton.

First of all, microscopical observations indicated that appreciable portions of the resin were deposited within the fibers. The effects produced on the stress–strain curves of the treated fibers, whether measured dry or wet, were undetectable in the first portions of the curves, but both breaking stress and breaking strain were reduced by the treatments. This behavior is consistent with that reported for keratin fibers in which additional cross-linking has been brought about by reactions with formaldehyde or with difunctional isocyanates. Another aspect of this work involved the relationship between the elastic recovery behavior of treated fibers and fabrics and the crease-recovery behavior of the fabrics. It should be noted, for many man-made fibers and for cellulosic fabrics treated with cross-linking resins, a strongly positive correlation between elastic recovery and fabric crease-recovery is usually observed. For wool, however, the effect of DMEU appeared to increase the elastic recovery of both single fibers and fabrics, but there was no apparent effect on the fabric crease-recovery. Furthermore, it was found that the elastic recovery in the wet tests was greater than in the dry tests, this difference being more pronounced for single fibers. The wet crease-recoveries of the fabrics were much lower than the dry crease-recoveries. Thus, in evaluating effects of DMEU treatments on this type of wool fabric, it is not possible to correlate fabric crease-recovery with fiber elastic recovery; in fact, a negative correlation was found upon comparing the results of wet and dry tests. It is possible that these findings may be explained on the basis of fiber-to-fiber interactions, resulting from the unique surface character of the wool fiber, but this is yet to be established.

Permanent Set and Supercontraction: Another current project is concerned with the permanent set and supercontraction of wool and other keratin fibers. Methods of imparting permanent set and supercontraction have been studied extensively, both in this country and abroad; more recently, such studies have been associated with efforts to impart "minimum care" properties to wool fabrics and have given rise to developments such as the *Si-Ro-Set* process in Australia and the *Immacula* process in England. Much of the literature in this field, however, is confusing in that conditions of experiment are incompletely specified. Thus, the TRI program was set up as a fundamental study of the mechanism by which keratin fibers experience set and supercontraction, under rigidly controlled and defined conditions, when given chemical treatments designed to rupture the fiber's cystine-disulfide bonds and/or its hydrogen bonds.

The keratin fibers chosen for the experiments were so selected that their "ortho-para" cortical structures differed widely.

The effects of setting in boiling water were studied for various keratin fibers, and it was found that setting generally reduced the stresses at various extensions along the stress–strain curve, including the stress at break; Young's modulus was also reduced. Although the breaking extension appeared to be reduced by the setting treatment, when allowance was made for the set imparted to the fibers, it was found that the breaking extension based on the original length of the untreated fiber was apparently unchanged. Studies were also made of the supercontraction of the same fibers in hydrogen-bond-breaking reagents, such as 9 molar solutions of lithium chloride. The two-stage nature of the supercontraction in such media, reported in the literature, was confirmed, and it appears that differences in supercontraction rates may be associated with differences in cortical structure.

Volume Changes Accompanying the Acid–Base Reactions of Keratin Fibers: The interactions which the acidic and basic side-chains of a keratin fiber's polypeptide chains undergo with one another and with inorganic and organic ions has been a subject of interest for some years and is related to the dyeing of keratin fibers with acid dyes. Thus, an investigation was undertaken to obtain information in this area by studying the volume changes which accompany the acid–base reactions of the ionizable side-chain groups. The volume of any protein-solvent system is related to the ionic charges present, because of the compression or electrostriction of solvent molecules by ionic charges. That is, the attractive forces between the charged sites of the protein and the surrounding solvent molecules tend to draw these molecules more tightly to the protein, causing the over-all volume of the system to be smaller than it would be in the absence of such charged sites. When keratin fibers—such as human hair and wool—react in aqueous suspension with strong acids or strong bases, the resulting reduction in the number of charged side-chains in the fiber causes an increase in the over-all volume of the system, which may be measured with a dilatometer. In this work, such volume changes were measured for human hair and wool reacting with a series of strong acids and bases in the presence as well as in the absence of various added salts.

A characteristic volume change was found to exist for each acid and base studied, and the magnitude of this volume change was related to the affinity of the anion for the fiber in the case of acids (e.g., chloride ion in the case of hydrochloric acid) and of the cation in the case of bases (e.g., sodium ion in the case of sodium hydroxide). Thus, the volume change observed in the case of hydrochloric acid was 9.6 ml./mole reacting, while that observed in the case of picric acid was about 17 ml./mole reacting, with the larger value in the latter

case reflecting the higher affinity of picrate anions for positively charged sites in the fiber. The volume changes for reaction of sodium hydroxide with wool fibers (11.4 ml./mole reacting) were found to be much lower than those observed when sodium hydroxide reacted with the basic groups of dissolved, oxidized wool. In this latter case, the volume changes were observed to be similar in magnitude to values reported for soluble proteins.

Optical Rotatory Properties of Dissolved Wool: Another research topic is concerned with measurements of the optical rotatory properties of solutions of both oxidized and reduced wools. In the cases of synthetic polypeptides and of some soluble proteins, such measurements have been of great value in elucidating the configurations of the polypeptide chains in solution and the effects upon these configurations of changing the local environment, i.e., changing the nature of the solvent. Polypeptide chains in solution are usually optically active and, by measuring the optical rotations of these solutions at different wave lengths of incident light, it is possible to relate the dependence of the optical rotation on wave length to the configuration of the polypeptide chain in the solution. The theory involved is fairly complex, and what is done is to compare the variation of optical rotation with wave length actually observed with that predicted by equations derived from the theory. Thus, for example, it has been shown that, even in solution, many polypeptides exist in the form of helical chains closely similar in configuration to that found for these same chains in the crystalline state. Where the hydrogen bonds responsible for the stability of the helical configuration are readily ruptured through interaction with a suitable solvent, the configuration of the polypeptide chain in solution is that of a random coil, i.e., completely unfolded.

The results obtained thus far for samples of dissolved wool are consistent with much of the data accumulated for other proteins. In the case of oxidized wool dissolved in concentrated urea solutions (random coil favored) with the urea subsequently removed from the wool by dialysis, the results indicate a gradual folding of a random structure with increasing removal of urea. In the case of wool dissolved in an equivoluminal mixture of dimethyl formamide and water, the results agree with the concept that less polar solvents favor a helical configuration.

Synthetic Fibrous Polymers

The introduction of synthetic fibers upon the textile scene during the past two decades and the ever increasing importance of these materials to the textile industry have made basic studies on synthetic polymers an important part of textile research. Thus, a significant segment of the TRI research program during 1960 dealt with the structure and properties of synthetic fibrous polymers.

The research topics covered in this section are concerned primarily with synthetic fibrous polymers although natural polymers have been included in some of these investigations. Conversely, not all of the TRI research program on synthetic fibers is covered in this section. In some investigations, such as the studies of fiber fatigue and surface properties, the chemical origin of the fibrous polymer is of secondary importance. The three topics discussed are Polymer Adsorption and Fractionation, X-ray Diffraction Studies, and Dyeing Studies.

Polymer Adsorption and Fractionation: A knowledge of the distribution of polymer chain length or molecular weight in any polymeric system is extremely important from an industrial point of view. The unambiguous experimental evaluation of a molecular weight distribution presents a highly challenging problem to the polymer scientist. Researches at Textile Research Institute during 1960 have dealt with the use of selective adsorption as a means of fractionating polymers according to molecular weight.

The amount of material which is adsorbed in a system in which a polymer solution is in equilibrium with a solid adsorbent is influenced by many variables. Thus, a systematic and statistically designed investigation was undertaken of the effects of such variables as temperature, agitation, time of sorption, particle size of adsorbent, average molecular weight of polymer, polymer to adsorbent ratio, and solvent characteristics. While this study is being performed on a particular cellulose nitrate, it is anticipated that much of the information will be generally applicable. This investigation, nearing completion, will provide the necessary background information for developing a system to adsorb a particular molecular weight component from a heterogeneous polymer mixture.

By careful control of the variables involved in the sorption process, it is possible to achieve fractionation according to molecular weight. The technique of selective adsorption has already been applied successfully to several polymeric systems, including polyvinyl acetate and cellulose acetate. There is every reason to believe that selective adsorption will prove to be a useful new method for determining the molecular weight distribution of any soluble polymer.

In view of the insolubility of cellulose in virtually all solvents, its molecular weight fractionation has been a particularly difficult problem. Recently several new solvents, some of them colorless, have been found for cellulose which allow the technique of selective adsorption to be applied directly to this most important fiber forming material. Examples of these solvents are: alkaline ferric tartrate and "Cadoxen" (cadmium oxide-ethylene diamine). Determination of the molecular weight distribution of cellulose by selective adsorption has been accomplished.

X-ray Diffraction Studies: The commercially important and scientifically interesting properties of synthetic polymers are manifestations of the rather complex chemical and physical structure of these materials. The polymer molecules in a textile fiber are arranged in a three-dimensional network where the degree of lateral order varies from that found in a true crystal to that which is best characterized as amorphous. While postulation of distinct crystalline and amorphous regions is an oversimplification of the true morphological structure, such a division represents a useful point of departure for many investigations on polymer systems. X-ray diffraction is an established technique for studying the crystalline regions in both natural and synthetic polymers.

Significant observations which contribute to our understanding of polymer structure have resulted from measurements of the thermal expansion coefficients of oriented polymer crystallites. Thermal expansion coefficients can be readily determined from X-ray diffraction data collected over a suitable temperature range. Polymeric materials such as nylon, Teflon,* Dacron,* polyolefins, cellulose, and natural rubber were studied between room temperature and that of liquid nitrogen ($-196°C$). In certain polymers negative expansion coefficients were observed along the chain direction. This observation was interpreted as indicating a continuous variation in molecular order from the crystalline to the amorphous state. Extension of these measurements to higher temperatures (200°C) and to polymers of varying crystallinities is planned in order to verify this interpretation of the observed negative expansion coefficients.

A long-range study of the relationships between the structure of synthetic polymers and the mechanical properties of films and fibers was initiated late in 1960. A large variety of synthetic polymers will be studied over a range of temperatures by both X-ray diffraction and mechanical-property measurements. The first phase of this program involves the elucidation of the effects of polymer crystallinity on torsional modulus.

Dyeing Studies: The transport of dyestuff from an external solution into the interior of a fiber structure is a complex process involving many variables. The kinetics of the dyeing process are influenced by such factors as temperature, molecular weight and shape of the dye, polymer structure, diffusion properties of the dye in the solution and in the polymer, and the partition coefficient of the dye between the solution and the polymer. The region at the boundary of the external solution and the fiber, known as the interface, may or may not present a significant barrier to the dyeing process. A theoretical and experimental investigation has been conducted to determine a parameter which will predict the effects of dye solution agitation on the rate of dyeing. New techniques for the detection and measurement of an interfacial resistance to mass transfer between two phases were also investigated.

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Microscopy Laboratory.

Based upon theoretical calculations, a dimensionless diffusion group of parameters, incorporating diffusion coefficients of the dye in the solution and in the polymer and the dyestuff's partition coefficient, was found to be a measure of the influence of agitation on the rate of dyeing. The importance of this dimensionless diffusion group was verified experimentally.

Other theoretical calculations indicated that the effect of an interfacial resistance should be relatively predominant for smaller systems, e.g., dyebath and fiber. The technique chosen for detecting and measuring an interfacial resistance involved the determination of experimental rate curves for two diffusion cells of different size. A significant difference in the rate curves obtained from the two cells indicated that an interfacial resistance exists for the transfer of a disperse dye from a water solution into a secondary cellulose acetate film.

In another investigation on the mechanism of dyeing, a long-range program on the effects of polymer structure on dyeing kinetics has been initiated. Dye absorption and desorption as a function of crystallinity and orientation will be investigated for a wide range of textile fiber-forming polymers. Initial experiments will involve the influence of orientation on the sorption kinetics.

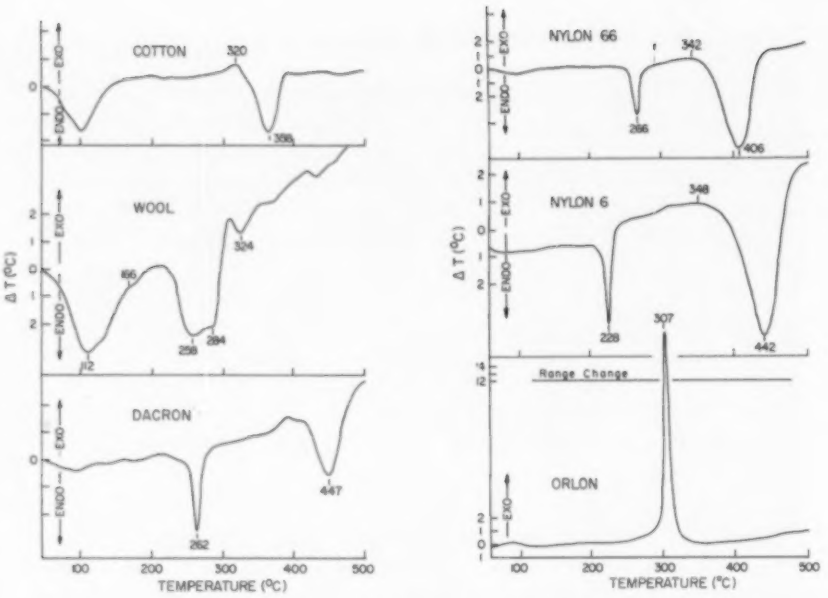
Thermal Behavior of Textile Materials

There is continuing interest in and requirement for textile systems that will resist attack by flames and which are also capable of functioning at high temperatures. In this connection there is need for detailed knowledge as to the thermal stability, mechanisms of thermal degradation, and high temperature reactions of natural and synthetic fibers. In addition, many important reactions that occur during textile processing, especially in certain finishing treatments, involve use of elevated temperatures. The nature of these reactions, however, is not well understood. The lack of basic knowledge in these areas has been due in large measure to the lack of suitable experimental techniques for probing and sorting out the many complex reactions involved. An important objective of the TRI program is the adaptation of old and new thermoanalytical techniques for this important area of textile research. At present, differential thermal analysis (DTA), thermogravimetric analysis (TGA) and gas chromatographic analysis (GCA) are being studied and used.

Differential Thermal Analysis: The chemical or physical changes that a substance undergoes during heating are accompanied by the absorption or the evolution of heat. Differential thermal analysis (DTA) is a method for detecting these changes as the sample is heated at a constant rate through the temperature range of interest. The DTA curve indicates the temperatures at which reactions occur, as well as the nature and magnitude of the reactions. The curves obtained are unique for each material so that a DTA curve can be used as a "fingerprint."

The sulfonic esters of cellulose, tosyl and mesyl cellulose, were studied and results indicated that levoglucosan formation is not involved in the thermal degradation but that a different mechanism obtains whereby the sulfonyloxy group is split off with the subsequent formation of sulfonic acid followed by acid degradation of the cellulose to form char. The thermal stability of these esters was appreciably lower than that of the unmodified cellulose. In addition, the thermal behavior of cyanoethylated cotton and the ethylenediamine-cellulose complex was examined. DTA data were also obtained on several synthetic fibers, which provided values of their second-order transition temperatures.

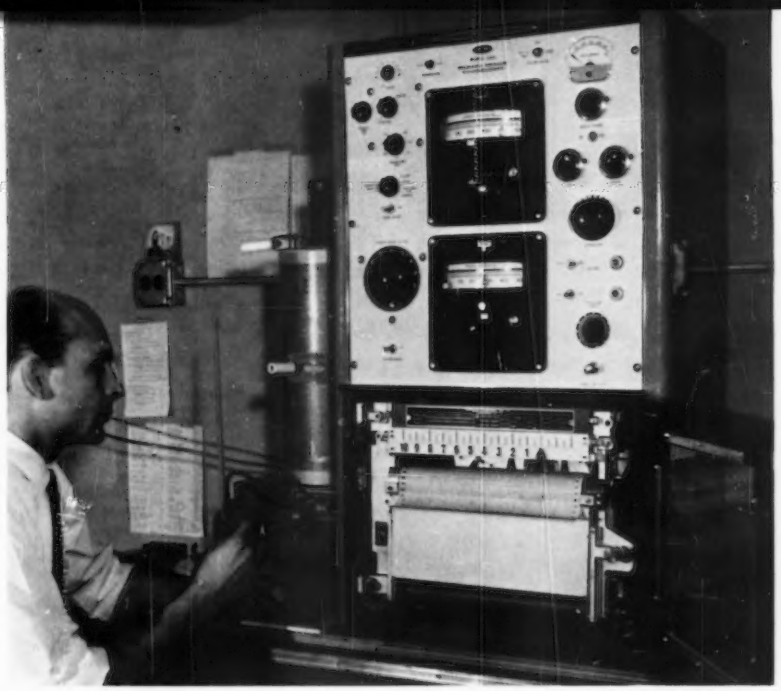
Thermogravimetric Analysis: A program has recently been initiated to develop apparatus for thermogravimetric analysis (TGA) as a supplement to differential thermal analysis (DTA) for evaluating the thermal behavior of textile materials. TGA involves the determination, on a continuous and quantitative basis, of the change in sample weight as a function of time and temperature. Such measurements may be made at a constant rate of temperature increase or at constant temperature. Because TGA curves represent quantitative weight



DTA curves, determined in nitrogen, for various textile materials. Temperature increase (rate of heating) 10°C./Min.

changes, they can be used to determine kinetic parameters such as rates of decomposition and orders of reaction. The data are also useful in interpreting more fully the DTA curves and, in conjunction with DTA data, in establishing the thermal stability of textile materials. Preliminary data have been obtained on cellulose and the sulfonic esters of cellulose. A spring-type deflection balance, using a linear differential transformer as transducer with automatic recording equipment, is being developed for this purpose. The equipment is designed so that samples may be run in controlled atmospheres.

Gas Chromatography: Knowledge as to the number and nature of volatile reaction products and thermal decomposition products is basic to any understanding of reaction mechanisms and paths. Standard organic chemical methods for determining such products are both time consuming and insensitive, and many mixtures are inseparable even by the more sophisticated techniques of paper chromatography. Gas chromatography overcomes most of these stumbling blocks, and a program is now in progress to determine polymer reaction products and thermal degradation products by this relatively new technique. For this purpose a high temperature gas chromatograph featuring both linear programming and isothermal operation was obtained. With this equipment, a wide range



Use of gas chromatography for analysis of thermal degradation products of textile materials.

of organic compounds with boiling points up to 500°C, and containing as many as 75 carbon atoms may be qualitatively and quantitatively determined. Suitable columns for the separation of aldehydes, ketones, organic acids, water, amines, and volatile gases were prepared. Thermal degradation products from the high temperature pyrolysis of cotton, nylon, and several rubbers were studied.

Thermal Characteristics of Coated Fabrics: Studies of the effects of textile coatings upon the behavior of fabric substrates have been continued with emphasis on fabric-coating interactions at elevated temperatures. Cotton and nylon fabrics, double-coated with Neoprene W,* butyl rubber, or Hypalon-20,* were examined. The fabrics, coatings, and fabric-coating systems were characterized and studied by differential thermal analysis. All elastomers were found to interact chemically with both cotton and nylon at temperatures greater than 275°C. Data were also obtained on the thermal degradation of the fabrics and coatings as separate materials. Pyrolysis studies were carried out and some of the degradation products determined by classical organic chemical techniques. Further work was done on the products of thermal decomposition by gas chromatographic analysis. The results confirm the conclusions, based on DTA studies, that there is chemical interaction.

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Flame- and Glow-Resistant Cotton Fabric Systems with Low Heat Transmission: In this project, the primary objective is the development of a flame- and glow-resistant fabric or fabric assembly with low heat-transfer properties. The treated fabric must also be non-fusible and is to be suitable for the fabrication of personnel parachute packs. Achievement of these objectives would afford protection of the nylon canopy in a parachute pack from flame and heat damage as well as elimination of pack malfunctioning due to fabric fusion. Cotton ducks were selected as base fabrics for treatment. Flame- and glow-resistant fabrics were obtained by: a) chemical modification involving mesyl ester formation, phosphorylation and bromine replacement of mesyloxy groups at carbon 6; b) APO-THPC treatment; and c) THPC-melamine treatment. The flame resistance, glow resistance, and mechanical properties of the chemically modified and resin-treated fabrics were evaluated by standard methods. The heat transmission of the treated fabrics alone and of combined fabrics (prepared by combining a treated fabric with untreated cotton poplin or nylon) was measured by means of an apparatus designed for the purpose. In the heat transmission test, a flame of known temperature was allowed to impinge on the front surface of the sample fabric for a specified period while the temperature at the back surface directly opposite the flame was measured by means of thermocouples. The results of flammability tests have shown the treatments for flame and glow resistance to be essentially equivalent. However, the chemically modified samples exhibited better mechanical properties. The heat transmission data have indicated that two-ply or combined fabrics are probably required to meet the stipulated standard. The flame-retardant treatment most effective in reducing heat transmission appears to be the THPC-melamine modification but, even so, a single ply of treated fabric is not quite adequate.

ROBERT F. SCHWENKER, JR.
Associate Research Director

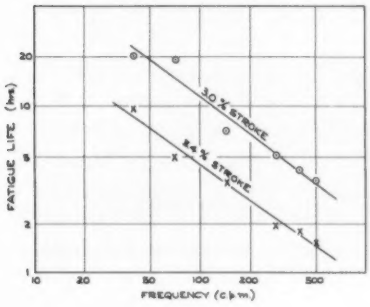
Physics of Fibers

Work in this field during 1960 embraced four research areas. Fiber fatigue studies were made with fibers cycled both in tension and bending provided by biaxial rotation. A new program on the surface characteristics of natural and synthetic fibers was initiated late in 1960. An investigation of the dependence of rupture properties of cotton fibers on their fibrillar structures was also conducted. Studies of the dynamic response of crimped filaments formed the basis of another program in fiber physics.

Obviously, many other fiber-physical studies have been in progress, as portions of other assignments, but only the four topics mentioned above are reported under this title, the Physics of Fibers.

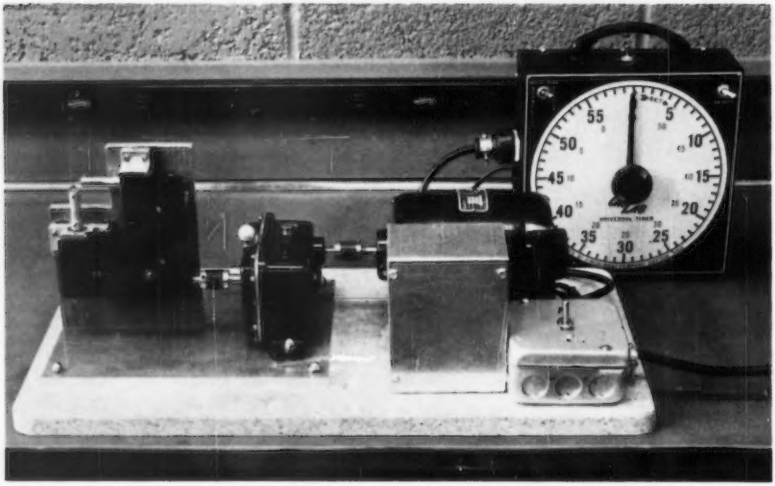
Fatigue in Textile Fibers: A multiple-station machine for fatiguing individual fibers, of various lengths, in cyclic longitudinal strain, was placed in service in 1960. On this machine, cyclic elongations up to 1 inch can be imposed on the fibers. Frequency is continuously adjustable from zero to 18 cycles per second. With this equipment, data have been obtained on a number of aspects of the fatigue of fibers in cyclic tension. Exploratory experiments, for instance, were conducted with a view to determining whether the length of a fiber specimen during fatiguing has an influence on the residual rupture properties. A viscose rayon sample was used in these experiments. While, in general, the fatiguing was found to reduce the elastic modulus and rupture properties, no trend in these properties that could be related to fatiguing length was disclosed.

In another experiment on an experimental acrylic sample, the results, analyzed statistically, indicated that the fatigue-lifetime data (for cyclic tension) are not normally distributed, but that the logarithms of the lifetimes are, in general, so distributed. Measurements of the fatigue lifetime of the same acrylic sample at five different frequencies of cyclic tension and two strokes revealed that the lifetime is a power function of the frequency, in agreement with earlier results of others on tire cord, and with theory. Fatigue lifetime does not appear to be a function solely of the number of cycles endured by the fiber sample.



Life of experimental acrylic fiber fatigued to rupture in longitudinal tension, as a function of frequency of straining.

A single-station machine for fatiguing fibers in biaxial rotation has been built and placed in operation. On this machine, the test fiber, in a bent configuration, is rotated on the axes of two shafts at right angles to each other. Rotary velocities from zero to 550 r.p.m. are attainable. An electric timer is provided so that any desired fatiguing time up to 60 hours may be selected.



Biaxial rotation, single-fiber fatigue tester.

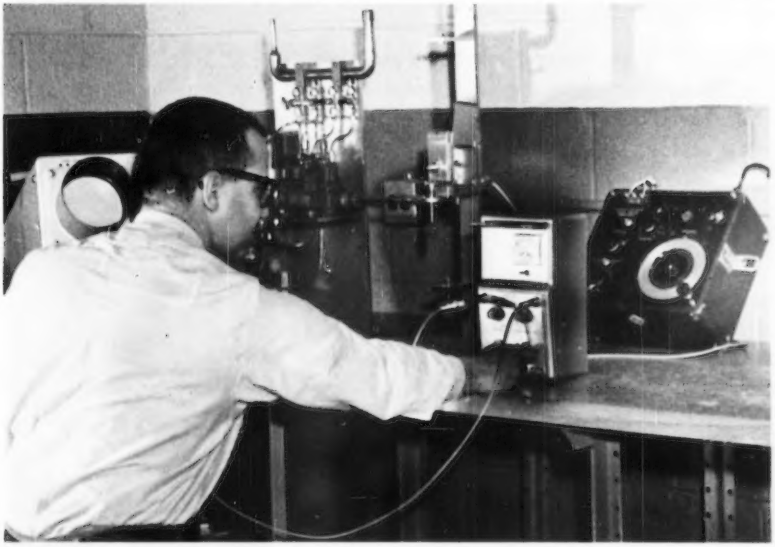
Nylon 66 and nylon 6 monofils, each type in three different diameters, were fatigued in biaxial rotation in a four-fold range of velocities. Rather than being fatigued to failure, the specimens were tested for breaking tenacity and extension after fatiguing periods of 30 minutes for one set and 45 minutes for another. The results indicated that, for most samples, the rupture properties decrease with increasing rotary velocities, though generally at a lower rate in the range of higher velocities. Increasing the fatiguing period from 30 to 45 minutes had the not unexpected effect of accelerating the deterioration in properties. The monofils of smaller diameter were less affected by the biaxial fatiguing, and by the increase in rotary velocity.

Microscopic examination has also been used in the study of fatigue in fibers. Such examination, by lateral view of the broken ends of fibers, as well as by comparison of successive fiber cross sections in the rupture region, revealed that in high-tenacity viscose, broken in cyclic tension, the rupture surface was substantially planar and normal to the fiber axis. No indications of fibrillation were found. Microscopic techniques have been applied to a number of monofils of both nylon 66 and nylon 6, fatigued in biaxial rotation at various velocities and

for different periods short of rupture. The resulting photomicrographs showed progressive development of diagonal fissures in the fatigued regions of the monofils, especially those of nylon 66, and of a bulbous expansion in the nylon 6 specimens.

Fiber Surface Studies: The work that has been underway for the past three years on the development of techniques for characterizing the geometric "roughness" of fiber surfaces has been expanded to embrace the study of the surface friction of single fibers. An improved apparatus, which, it is believed, further isolates the sensitive pickup from extraneous vibration, has been constructed for the actual scanning of the fiber surface in the roughness measurements. An electronic system, based on new concepts and employing more compact units than were previously used, has been designed for the recording of roughness parameters, and is presently being assembled. For the measurement of surface friction, another sensitive device, employing the principle of the torsion balance to sense the frictional force, is being built. This will be used in conjunction with an electrical bridge circuit and other electronic components, for registering the frictional parameters.

Plans for the initial use of this equipment are pointed toward exploring the relationship between the geometric roughness and the frictional characteristics



Apparatus for the measurement of frictional forces between fibers.

of a wide variety of fiber types. A subject of special scrutiny will be evidences of "stick-slip" phenomena, and their dependence on the number and magnitude of surface asperities. In this connection, it is planned to make microscopic measurements of the area of contact between crossed fibers as a function of the force producing the contact, with a view to gaining some insight into the influence of the so-called "geometric" area on inter-fiber friction.

Dependence of Rupture Properties on the Fibrillar Structure of Cotton Fibers: Exploratory studies have been initiated on both raw and mercerized cotton to determine whether the breaking load, the character of the rupture surface, and the regularity or other features of the fibrillar structure of an individual fiber can be related to each other. Earlier studies have produced evidence that breakage in cotton fibers tends to occur at the reversals in the helical orientation of fibrils. The present investigation aims to obtain fuller information on this point, and to uncover other possible relationships of similar nature. The procedure has been to break a number of single fibers in a conventional tensile test, identifying the breaking load of each fiber, and then to examine the rupture regions of the particular fiber under the microscope, using elliptically polarized light. An early, though incidental, disclosure of this study was that mercerization severely reduces the spread in individual breaking loads found in particular cotton samples.

Dynamic Response of Crimped Filaments: The behavior of the filaments in a thread in sewing, for example, or in a warp yarn in weaving, where rapid, cyclic, lateral loading is involved, is important to the success of these operations. It has been recognized that there are conditions, such as certain frequencies of cyclic loading, under which detrimental effects, if not actual breakage of the

W. James Lyons
Associate Research Director

thread or yarn, could occur. The mechanical problem becomes more complicated when the component filaments are crimped. As a basic step toward dealing successfully with this problem, the case of filaments having two-dimensional (coplanar) crimp was considered, and a theoretical method developed for calculating the natural frequencies of vibration of such filaments. Only free vibrations were treated, and the filaments were assumed to be elastic. The approach to the analysis was the development of the governing differential equations of motion of a coplanar filament with an arbitrary initial configuration. Such equations were developed, taking into consideration the effect of bending only, in one case, and the effect of both bending and stretching, in another. Solutions of the equations were then derived or outlined, so that the natural frequencies of vibration could be calculated for different filament diameters and lengths, as well as for different methods of supporting the filament. Four such methods were treated: a) both ends of the filament rigidly clamped; b) both ends rotatable in the plane of the crimp; c) one end rigidly clamped and the other free (as in a cantilever); and d) one end clamped and the other rotatable. In particular, expressions were obtained for the natural frequencies of the first three modes of vibration of a filament clamped at both ends. In an independent but related study employing fine steel filaments, the theoretical results for this latter case were gratifyingly confirmed.

Properties of Fiber Assemblies

It is impracticable to include all of the TRI effort on yarns and woven fabrics under this title since much of this work falls more logically within the scopes of other headings. Thus, only four topics, specifically related to fiber assemblies, are reported here.

Studies of Nonwoven Fabrics: This program in chemical engineering is designed to provide an analysis of the properties of certain types of nonwoven fabrics in terms of the principal fiber and construction variables, using the "response surface" statistical approach. Apparatus for producing experimental nonwoven fabrics on a laboratory scale is in the course of construction and active experimentation will begin in 1961.

Transverse Deformation of Grillages: It is hoped that this assignment in mechanical engineering may be the beginning of an extensive, long-range program on the performance of fabrics (special cases of "grillages"). The initial theoretical analysis involves the deformation of two perpendicular filaments,

loaded transversely. It is assumed that filament ends are fixed and that one filament rolls upon the other without slipping. The principle of minimum potential energy is being used to obtain the governing equations. Apparatus for the experimental work is also under consideration; for example, it may be necessary to employ a small wind tunnel to achieve the desired loadings.

Monograph on Impact Phenomena in Textiles: Work on this monograph, covering all published and much unpublished research in this field, has continued in 1960. The extensive bibliography is now essentially complete and several chapters have been written. This program, supported by a government contract, will be completed in 1961 and should yield a monograph of considerable value to the many workers interested in impact testing of textiles.

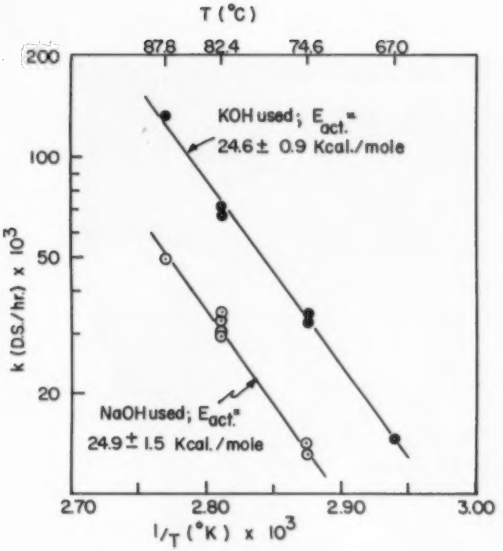
Potential of Radioisotopic Methods in the Textile Industry: This government-sponsored effort was pursued in 1960. The program required extensive discussions with various firms in the textile field, in order to project possible industrial applications of radioisotopes. A comprehensive report was prepared on the basis of these studies which, with permission of the sponsoring agency, was sent to Official Representatives of all TRI member firms.

Chemical Treatments of Cotton

For the past year, two long-range projects have been concerned with chemical treatments of cotton. In one of these, the emphasis has been on reactions which improve the resilience of cotton, so important to its performance in minimum-care fabrics. In the other project, studies have been made of the response of various cottons to chemical treatments for the purpose of characterizing differences in their behavior and relating these differences to fiber morphology and fine structure.

Resilience of Chemically Modified Cottons: The over-all purpose of this project is to establish a sound quantitative picture of the chemical and physical changes accompanying chemical reactions that improve the resilience of cotton. To this end, the reactions employed were chosen with a view to reducing the chemical complexity to a minimum in order to produce chemical and physical changes capable of unambiguous interpretation.

Studies were carried out on the reactions of alkali celluloses and sodium cellulosates with methylene dibromide. The reactions in these cases involved cotton cellulose in a swollen state and resulted in treated fabrics exhibiting improved wet crease-recovery, but with unchanged or poorer dry crease-recovery



Effects of temperature on the rates of reaction of alkali celluloses with methylene dibromide.

as compared with untreated fabric. Studies were also carried out on the reactions of cellulose with formaldehyde under acid conditions. Here, the treatments involved cotton cellulose in a dry or relatively unswollen state and resulted in the treated fabrics exhibiting improved crease-recovery both dry and wet.

The rates of reaction of methylene dibromide with alkali celluloses prepared from potassium hydroxide were found to be more than double those with alkali celluloses prepared from sodium hydroxide. The energies of activation for the reactions were found to be the same for both kinds of alkali cellulose and are consistent with the view that covalent bonds are being formed in the course of the reactions. In the reactions of sodium cellulosates with methylene dibromide, proper care being taken to exclude water from the reaction system, it was found that the reproducibility of repeat experiments was quite good and that the rate of reaction of the sodium cellulosate with methylene dibromide was much greater than that of an alkali cellulose prepared from sodium hydroxide.

In connection with the studies of the reactions of cotton cellulose with formaldehyde under acid conditions, the effects of boiling 1% acetic acid solution on the treated fabrics were observed. The acetic acid was found to reduce the acetal content of the treated fabrics and to cause corresponding decreases in both dry and wet crease-recovery improvement. The reproducibility of these treatments, with respect both to extent of formaldehyde incorporation and to dry and wet crease-recovery, was found to be very good within a single treatment and, more important, between different treatments carried out under the same conditions.

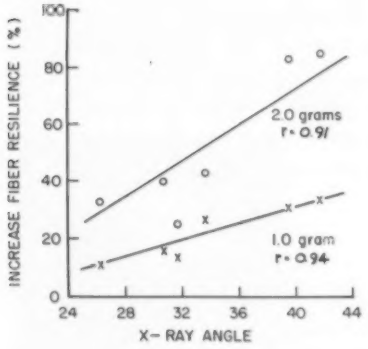
Experimental chemical treatment of cotton fabric to improve its resilience.

Response of Different Cottons to Chemical Treatments: In many chemical treatments of cotton, such as mercerization or resin finishing, careful attention is given to the control of process variables such as concentration, time, and temperature, but another variable—the cotton fiber itself—is not ordinarily considered. Actually, however, it is known that appreciable differences in fiber morphological and fine-structure characteristics exist among the many varieties and strains of cottons available today. In particular, differences have been shown to exist in the fibrillar orientations of various cottons, and it has also been shown that these orientations may be reliably estimated by the X-ray angles determined from X-ray-diffraction measurements. The relationship between fibrillar orientation and X-ray angle is an inverse one; i.e., high orientation fibers exhibit low X-ray angles. In earlier work, experiments were carried out to determine whether different cottons respond differently to chemical treatments,

and it was found that they do. For example, in the case of six widely different cottons subjected to mercerization, it was found that greater relative changes in mechanical properties were caused by mercerization of single fibers from cottons of relatively low fibrillar orientation (high X-ray angle).

During this year, a similar study was carried out on eleven different experimental cottons but, in this case, yarns of optimum twist for each of the cottons were subjected to mercerization. Here, it was found that greater relative increases in yarn elastic modulus and resilience were caused for the cottons of high fibrillar orientation, and these relative increases for yarn elastic modulus were much smaller than those observed for fiber elastic modulus. The fundamental difference between the single-fiber and yarn mercerization experiments appears to be that in the fiber treatments the changes in properties reflect only the changes in fiber fine structure, whereas in the yarn treatments the changes in yarn properties involve changes in fiber fine structure and yarn constructional characteristics as well.

A study was also carried out on the response of six widely different cottons to a resin-finishing treatment employing dimethylol ethyleneurea. The treatment was carried out on skeins of yarns held at constant length, and the mechanical properties of fibers withdrawn from the yarns were measured. The results of these measurements indicated that the resin-finishing treatment causes greater increases in fiber resilience for the cottons of lower fibrillar orientation. Experiments are now underway in which the fibers are under controlled tension during the resin-finishing treatment.



Increase in single fiber resilience resulting from a yarn resin-treatment as a function of raw cotton x-ray angle. Fiber resilience is measured from a 1.0 gram and a 2.0 gram loading.

GRADUATE EDUCATION

A basic change in Research Fellowship regulations, a significant expansion in the TRI student body, and the addition of two eminent scientist-teachers to the TRI faculty were the highlights of developments in the TRI graduate education program during 1960. Functioning under the administrative supervision of Dr. L. Rebenfeld, the educational program continues to serve its important function through research and through the training of scientists at the graduate level.

In order to emphasize the truly academic nature of TRI Research Fellowships, a basic change in the Fellowship regulations was adopted, effective with the academic year 1960-1961. Conforming with usual university practice, the basic tenure of a TRI Research Fellowship has been changed from a calendar year to an academic year. Predoctoral Fellows are appointed for a nine-month academic year, beginning each September, at a total stipend of $1500. During the three summer months a TRI Research Fellow is free to pursue whatever activity he wishes. Normally, at the conclusion of his first academic year a student is advised to gain industrial research experience during the summer months. Advanced students, who are actively conducting their thesis research assignments, are urged to continue their research during the summer months. In these cases, students receive "summer research grants" in the total amount of $500 so that they may pursue their research uninterruptedly. It is felt that these new regulations will make TRI Research Fellowships even more attractive to qualified candidates.

Charged with the responsibility of guiding our graduate students in their research assignments are a group of distinguished scientist-teachers who constitute the TRI faculty. Dr. Arthur V. Tobolsky, Professor of Chemistry, and Dr. Hugh S. Taylor, Professor Emeritus of Chemistry and Dean Emeritus of the Princeton University Graduate School, have joined the TRI scientific community, acting as thesis advisors to students in physical chemistry. Continuing in the important capacity of thesis advisors are Professor Walter J. Kauzmann in physical chemistry, Professor Emeritus Eugene Pacsu in organic chemistry, Professor John C. Whitwell in chemical engineering, and Professor Edward W. Suppiger in mechanical engineering.

Predoctoral Research Fellows

Predoctoral Research Fellow Graham K. Morbey sustained the Final Public Oral Examination during 1960, thus earning his Ph.D. degree from Princeton University in chemical engineering. This brings to 38 the number of Ph.D. degrees granted by Princeton University to TRI Research Fellows. Dr. Morbey, whose thesis dealt with the spinning of polymer-blend fibers, is now employed by the Dunlop Rubber Company, and it is gratifying that he is continuing active research in the fiber field with a TRI member company.

Research Fellow William D. Freeston has completed his thesis research in mechanical engineering. His study of the dynamic response of crimped fibers has been accepted as a doctoral dissertation by Princeton University and we look forward to adding his name to the growing list of successful TRI Research Fellows as soon as his Final Oral Examination is sustained. Mr. Freeston has also accepted employment with a TRI member company, Fabric Research Laboratories, Inc., where he is continuing his research activities in the field of textile science.

Research Fellows Thomas J. Cochrane, Jr. and Robert P. Teulings, both in chemical engineering, are completing their thesis research assignments and expect to submit their dissertations to Princeton University in the near future. Similarly, Research Fellows Leonard Lifland and Donald D. Kasarda are completing their thesis research in organic chemistry and physical chemistry, respectively. We count on adding these four men to our list of successful TRI Research Fellows.

Mr. Henry W. Saffer, Research Fellow in physical chemistry, and Mr. John A. Regalbuto, Research Fellow in mechanical engineering, have sustained the crucial General Examination during 1960. These men are now pursuing their thesis research on a full-time basis.

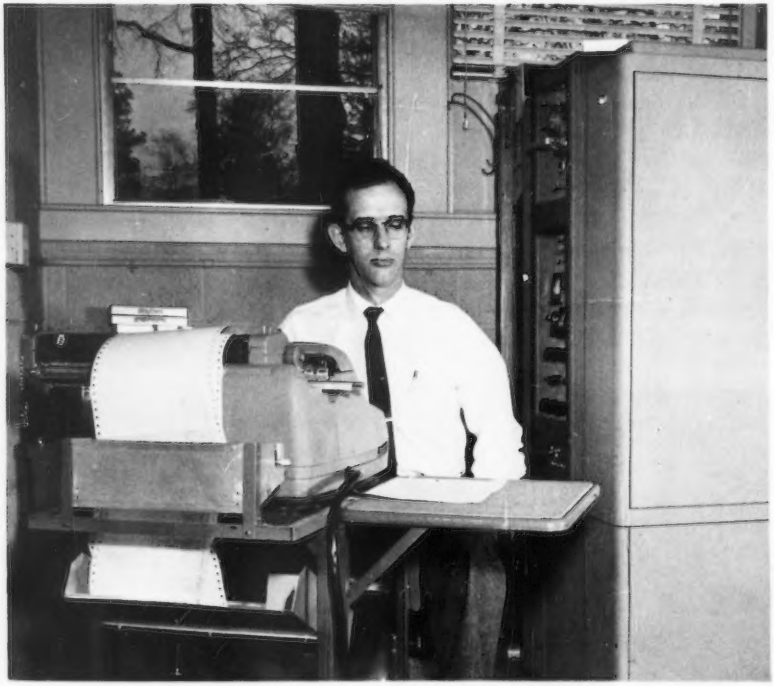
Mr. Gerald H. Bjorge, Research Fellow in chemical engineering, who has successfully sustained his qualifying examinations, must face the General Examination in 1961. He has begun preliminary investigations on his thesis research assignment.

During 1960 five new predoctoral Research Fellows were appointed—Mr. Volker D. Arendt and Mr. Jonathan B. Rivlin in organic chemistry, Mr. Gerd N. LaMar and Mr. George T. Davis in physical chemistry, and Mr. Elliot B. Grover in mechanical engineering. These men, who are only at the beginning of the long road toward a Princeton University doctorate, must pay particular

LUDWIG REBENFELD
Associate Research Director

attention to many courses and qualifying examinations during their first year as TRI Research Fellows. Despite the heavy burden of a first-year schedule, several of these men have begun a preliminary research assignment which will eventually allow them to select a suitable thesis topic.

Of the twelve Research Fellows now active at TRI four are expected to complete their work early in 1961. This means that new Fellows must be found for the academic year 1961-1962. An active campaign for seeking qualified candidates for TRI Research Fellowships is always underway. The rigorous entrance requirements set by both Textile Research Institute and Princeton University severely limit the number of applicants who may be awarded one of our Research Fellowships. We have been extremely fortunate so far in gathering a group of Research Fellows with the qualifications to pursue graduate studies at Princeton University and with research interests in the fiber field. The further success of the TRI graduate education program is dependent upon our continued ability to select the highest caliber men for our predoctoral Research Fellowships.



The electronic computer gets late evening and week-end use by TRI Research Fellows.

Postdoctoral Fellows

A graduate educational program based almost entirely upon research rather than upon formal lectures is significantly enhanced by a group of postdoctoral Fellows, who, in view of their advanced scientific standing, create an atmosphere conducive to research. Over the years our postdoctoral Fellows along with the permanent TRI staff have been instrumental in creating for our graduate students just such an atmosphere of research. In several cases TRI postdoctoral Fellows have provided research guidance for our graduate students in cooperation with the student's thesis advisor. We are eager to enlarge our group of postdoctoral Fellows but must, of course, consider budgetary and space limitations. Three postdoctoral Fellows were active at Textile Research Institute during 1960.

Dr. Aldo Busacca, whose interesting research in the measurement of fiber surface characteristics, following up the pioneering experiments of Dr. Lyons, has formed the basis of a new group-supported project, completed his assignment as a postdoctoral Fellow during 1960.

Dr. P. J. Kangle, an organic chemist from the University of Bombay in India, began a postdoctoral appointment at TRI under the sponsorship of the International Cooperation Administration. Dr. Kangle has been working in the field of polymer fractionation by selective adsorption under the guidance of Professor Eugene Pacsu.

Dr. V. D. Gupta, Assistant Professor of Physics at the University of Allahabad in India, began a postdoctoral assignment at TRI in physics during 1960. Dr. Gupta's wide research background in X-ray diffraction studies of polymers is being brought to bear on our own interests in this field. He is working under the direction of Dr. J. H. Dillon and Professor A. V. Tobolsky.

Visiting Fellows

Unfortunately our group of Visiting Fellows is a small one indeed. Mr. Makoto Yanaka, whose work at TRI had been sponsored by the Mitsui Trading Company, completed his appointment during 1960. Mr. Yanaka had been studying the nature of free hydroxyl groups in a secondary cellulose acetate under the direction of Dr. L. Rebenfeld.

It is hoped that this important category of our student body may be significantly expanded in future years. The opportunity for industrial scientific personnel to gain fiber and polymer research experience at TRI is a means whereby the Institute can provide direct benefit for a member company at nominal cost.

Fellowship Grants

The system of Fellowship Grants which was instituted in 1959 has successfully continued and expanded in 1960. A Fellowship Grant allows a donor to support directly the TRI graduate education program thus relieving the burden which this program places on our general funds. Two new Fellowships were created in 1960—the Cone Mills Fellowship in Organic Chemistry and the Celanese Fellowship. These Fellowships, added to our previously awarded Fellowship Grants from Courtaulds, Inc., U.S. Rubber Company Foundation, The Camille and Henry Dreyfus Foundation, Union Carbide Chemicals Co., and Johnson and Johnson, brings to a total of seven the number of such Grants awarded. While graduate students who have been assigned to one of these Fellowships receive no additional financial benefit, attention is given to selecting recipients whose scientific interests are in concert with the donors' area of specialization. During 1960, Research Fellows assigned to sponsored Fellowships and the respective donors were as follows:

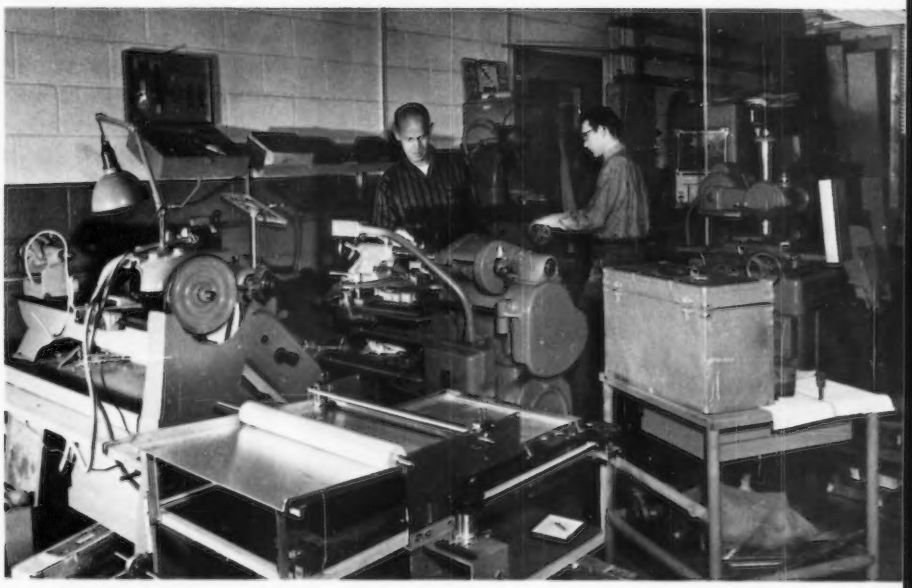
THOMAS J. COCHRANE, JR.	Courtaulds, Inc.
DONALD D. KASARDA	U.S. Rubber Company Foundation
LEONARD LIFLAND	The Camille and Henry Dreyfus Foundation
GERALD H. BJORGE	Johnson and Johnson
HENRY W. SAFFER	Union Carbide Chemicals Co.
GERD N. LA MAR	The Celanese Corporation of America
VOLKER D. ARENDT	Cone Mills Corporation

Advisory Committee on Education

An educational program, in order to serve best the interests for which it is designed, needs constant scrutiny, evaluation, and self-criticism. The Advisory Committee on Education provides a means of conducting a periodic examination of the TRI educational program. This committee, which is an outgrowth of a Board of Trustees Committee on Education, is composed of leading educators and scientists who meet periodically with the TRI staff to review the status of the educational program. The first such meeting was held in Princeton, New Jersey on May 27, 1960.

The Research Library

The Instrument Shop



DISSEMINATION FUNCTIONS

Publications Department

It is a pleasure to report that the Institute's Publications Department has not only maintained the quality of our principal publication, *Textile Research Journal*, but also has developed a modest but impressive excess of income over expense. In addition, *Institute Membership News* has been issued with reasonable regularity, *Notes on Research* have been sent to TRI company members, and important assistance in editing the *TRI Annual Report* has been given. Principal kudos for this most satisfactory performance must be given to Dr. Richard K. Toner who took over as Director of Publications in May 1959. Incidentally, Dr. Toner has continued his teaching career as Associate Professor of Chemical Engineering at Princeton University and serves as Associate Priest of Trinity Episcopal Church of Princeton.

Dr. Toner gives full credit for the details of journal production to Miss Candy Frenking (as of December 31, 1960, Mrs. Karl Jens) who filled the position of Production Editor so well during the period June 1957–December 1960. She also served as Editor of *Institute Membership News*. Dr. Toner further points out the important contributions of the business office in handling those aspects of the Publications Department dealing with subscription records, billings, reprint sales, etc.

It is certainly gratifying that Mrs. Dorothy Hollmann, an experienced technical editor, accepted the position of Production Editor and was able to start work with TRI a few weeks before Miss Frenking left. Thus there should be no lack of continuity in the mechanics of production of *Textile Research Journal*, which is internationally acclaimed as an outstanding vehicle for the dissemination of textile research.

RICHARD K. TONER
Director of Publications

Seminars

TRI seminars have continued in their dual role of placing important research findings before industrial scientists for informal discussion and keeping TRI staff and Fellows abreast of scientific developments, within the Institute's laboratories and elsewhere. Attendance at seminars has been excellent, in spite of bad snowstorms which limited travel on two occasions. Subjects, speakers, and dates of the 1960 seminars, organized by Dr. Rebenfeld, are given in the Appendix.

It is important to note again that seminar speakers are not asked to submit manuscripts of their talks. Thus it is impossible to comply with requests for copies of the presentations. We plan to maintain this policy as it encourages informality and discussion and does not exclude presentation of very recent findings, which is often the case in scientific meetings for which advance manuscripts are required.

Annual Meeting

The Thirtieth Annual Meeting, held on March 24-25, was certainly a significant event in the textile research year 1960. A near-record attendance of 640 persons attests to the importance and timeliness of the technical papers presented. The whole program is given in the Appendix.

The featured luncheon address on *The Enigma of Liquid Space* by The Honorable James H. Wakelin, Assistant Secretary of the Navy, Research and Development, was intensely interesting. Many present expressed pleasure in having Dr. Wakelin, former TRI staff member, appear in this role. The presentation of Honorary Fellowship to Herbert Hoover was made *in absentia,* but nevertheless proved interesting to many who were not aware of the important part Mr. Hoover played in originating the Textile Foundation (the one-time companion organization of TRI) while he was Secretary of Commerce.

The Honorable James H. Wakelin, Assistant Secretary of the Navy, Research and Development, addressing luncheon guests at TRI's 30th Annual Meeting.

Professional Activities

The tabulations of *Professional Activities* and *Papers Presented* in the Appendix reflect the Institute's policy of encouraging participation of the staff in the affairs of scientific societies and trade associations. Such activities are time consuming and involve considerable expense, but TRI feels that its scientists should carry their full share of the responsibility for the operation of scientific bodies. Presentation of the work of staff and Fellows for broad scrutiny by the scientific and industrial communities is considered a vital function of the Institute. Indeed, the lists of *Papers Presented* and *Papers Published* constitute a good criterion of TRI research productivity.

INSTITUTE SUPPORT

Institute support continued to improve in 1960 but, referring to the figures of the accompanying table, it will be noted that total income increased by only $20,000 over that received in 1959. Yet, the increasing total income in the period 1958-60 is gratifying, particularly in that the major gain from 1959 to 1960 was in membership dues income. The continuing growth in Publications Department income is also encouraging.

TRI INCOME—1960 vs. 1958 and 1959

	1958	1959	1960
GENERAL INCOME			
Membership dues	$106,836	$110,929	**$122,496**
*Less credit to Pub. Dept.	(11,102)	(13,702)	**(14,419)**
Fellowship Grants	12,750	16,367	**15,833**
Miscellaneous	3,426	2,600	**2,572**
Publications Dept.	50,930	60,822	**65,988**
Total General Income	$162,840	$177,016	**$192,470**
PROJECT INCOME			
Group projects	$ 90,652	$142,462	**$149,953**
Government projects	60,423	75,954	**67,469**
Individually sponsored projects	58,984	44,353	**49,743**
Total Project Income	$210,059	$262,769	**$267,165**
Total Income	$372,899	$439,785	**$459,635**

*This is a credit to the Publications Department for subscriptions to *Textile Research Journal* furnished to TRI members.

Granting that the current support picture is rather good, it must not be assumed that the immediate future will be quite as bright. TRI still is subject to the caprices of business cycles, and the recession of late 1960 will probably produce setbacks. These must be surmounted and it will require intensified efforts by the Trustees and staff to maintain or advance the income position achieved by TRI in 1960.

FINANCES

Following the close of the Institute's fiscal year on December 31, 1960, Haskins and Sells, Certified Public Accountants, Newark, New Jersey, completed an audit of the Institute's financial position as of that date. There are presented on the following pages a certified balance sheet and a statement of income and expenditures for the twelve-month period then ended.

ACCOUNTANT'S OPINION

We have examined the balance sheet of Textile Research Institute as of December 31, 1960 and the related statement of income and expenses and operating deficit for the year then ended. Our examination was made in accordance with generally accepted auditing standards, and accordingly included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances.

In our opinion, such financial statements present fairly the financial position of the Institute at December 31, 1960 and the results of its operations for the year then ended, in conformity with generally accepted accounting principles applied on a basis consistent with that of the preceding year.

Newark, N. J.
March 1, 1961

HASKINS & SELLS
Certified Public Accountants

TEXTILE RESEARCH INSTITUTE

STATEMENT OF INCOME AND EXPENSES AND OPERATING DEFICIT

FOR THE YEAR ENDED DECEMBER 31, 1960

OPERATING INCOME AND EXPENSES:		
General income and expenses:		
Membership dues (less $14,419 allocated to Publications Department)	$108,077	
Special contributions (research fellowships)	15,833	
General income	123,910	
Less general program expenses—research and graduate education	106,134	$ 17,776
Group supported projects:		
Income	149,953	
Expenses	163,616	(13,663)
Individually supported projects:		
U. S. Government:		
Income	67,469	
Expenses	67,538	(69)
Non-government:		
Income	49,743	
Expenses	50,246	(503)
Publications Department:		
Income	65,988	
Expenses	59,437	6,551
EXCESS OF OPERATING INCOME OVER OPERATING EXPENSES		10,092
OTHER INCOME		2,572
EXCESS OF INCOME OVER EXPENSES		$ 12,664
OPERATING DEFICIT—January 1, 1960		$149,501
DEDUCT EXCESS OF INCOME OVER EXPENSES AS FOLLOWS:		
Income	$459,635	
Expenses	446,971	12,664
Remainder		136,837
SURPLUS CHARGE—Adjustment relating to projects completed in prior years		2,350
OPERATING DEFICIT, DECEMBER 31, 1960		$139,187

The Notes to Financial Statements should be considered in connection with this statement.

TEXTILE RESEARCH INSTITUTE

Balance Sheet, December 31, 1960

ASSETS			LIABILITIES		
GENERAL FUNDS					
Cash		$ 84,402	Accounts Payable		$ 16,263
Accounts Receivable:			Unappropriated Textile Foundation Grant		49,060
U. S. Government	$ 21,715		Unexpended Project Receipts:		
Other	4,265	25,980	Non-government	$101,725	
Supply Inventory—At average cost		5,469	Government	2,112	103,837
Deferred Charges, Etc.		4,795	Deferred Dues, Subscriptions, Etc.:		
			Membership dues	55,861	
			Subscriptions	23,137	
			Participating and visiting fellowships	11,675	90,673
			Operating Deficit		(139,187)
Total		$120,646	Total		$120,646
PROPERTY FUNDS					
Cash		$ 3,845	Accounts Payable		$ 4,481
Property—At cost:			Mortgage Payable		18,536
Land and improvements	$ 17,647		Property Funds Principal (no change during year)		312,791
Buildings and improvements	213,685				
Laboratory equipment and tools	139,156				
Furniture and fixtures	36,521				
Library	7,838				
Automotive equipment	4,811				
Maintenance equipment and tools	3,594				
Total property	423,252				
Less depreciation accumulated since January 1, 1956	91,289	331,963			
Total		$335,808	Total		$335,808

The Notes to Financial Statements should be considered in connection with this balance sheet.

TEXTILE RESEARCH INSTITUTE

Notes to Financial Statements
for the Year Ended December 31, 1960

1. Income from dues, subscriptions, and fellowships is recorded, with minor exceptions, only as received and deferred to the extent of any prepayment thereof. Project income is accrued only to the extent of the recoverable unreimbursed expenditures applicable thereto, or deferred to the extent of the unexpended balances.

2. The Institute has established a non-contributory employee pension plan effective January 1, 1960. All full-time employees are eligible to participate in the Plan if, on its effective date or any anniversary of such date, they have attained age thirty and are under age sixty. The Plan is being funded through the purchase of individual annuity policies from an insurance company and is being administered by a bank, acting as Trustee. The Institute intends to continue the Plan indefinitely but has reserved the right to revise or discontinue the Plan. Total cost applicable to the Plan for the calendar year 1960 aggregated $15,418.

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COMPANY MEMBERS

(during 1960)

Ahmedabad Textile Industry's Research Association
Albany Felt Company[1, 2]
Althouse Chemical Company
American Association of Textile Chemists and Colorists
American Cyanamid Company[4, 5]
American Enka Corporation
The American Thread Company, Inc.[3]
American Viscose Corporation[4, 5]
Arkansas Company, Inc.

Bachmann Uxbridge Worsted Company[1]
The Barre Wool Combing Company, Ltd.[1]
Belding Heminway Company, Inc.
Bell Telephone Laboratories, Inc.
Geo. W. Bollman & Co., Inc.[1]
John H. Breck, Inc.[1]
Bryant Chemical Corporation
Burlington Industries, Inc.[1, 4]

Canadian Industries Limited
Cascade Woolen Mill
Celanese Corporation of America[2, 5, 7]
The Chemstrand Corporation[2, 5]
Sté. Chimiotex[5]
CIBA Company, Inc.
Clemson Agricultural College, School of Textiles
Coats & Clark Inc.[3, 5]
Cold Spring Bleachery
Colgate-Palmolive Company[1]
Cone Mills Corporation[3, 4, 7]
Corn Industries Research Foundation, Inc.
The Cotton Research Committee of Texas
Courtaulds (Alabama) Inc.[7]
Cranston Print Works Company[2]

Dan River Mills, Incorporated
Deering Milliken Research Corporation[1, 2, 4]
W. J. Dickey & Sons, Inc.
The Dow Chemical Company
E. F. Drew & Co., Inc.
Drycor Felt Company
Dunlop Research Centre[5]
E. I. du Pont de Nemours & Co., Inc.[2, 5]

Eastman Chemical Products, Inc.
Esso Research and Engineering Co.
Evans Research & Development Corp.

Fabric Research Laboratories, Inc.[3]
Food Machinery & Chemical Corporation

General Electric Company
The General Tire & Rubber Company
Georgia Institute of Technology, A. French School of Textiles
The Gillette Company[1]
Otto Goedecke, Inc.
J. B. Goldberg
B. F. Goodrich Chemical Company

The Harodite Finishing Company, Inc.
The Hart Products Corporation
Hercules Powder Co., Inc.
Huyck Corporation[1]

Imperial Chemical Industries, Ltd.
Industrial Cellulose Research Limited
Industrial Rayon Corporation

Joanna Cotton Mills Company[3]
Johnson & Johnson[3, 7]

Kimberly-Clark Corporation[6]

Arthur D. Little, Inc.
Lowell Technological Institute Research Foundation
M. Lowenstein, Inc.[4]

Marriner Combing Company[1]
C. H. Masland & Sons
Otto B. May, Inc.
Mohasco Industries, Inc.
Philip Morris Incorporated

National Aniline Division, Allied Chemical Corp.[5]
National Cotton Council of America[2, 4]
North Carolina State College, School of Textiles[3]

Pepperell Manufacturing Company, Inc.[3, 4]
Philadelphia College of Textiles and Science
The Procter & Gamble Company

Quaker Chemical Products Corporation[4]

Riegel Textile Corporation[3]
Rohm & Haas Company[4]

Saco-Lowell Research & Development Center
Scholler Brothers, Inc.
Eugene W. K. Schwarz, Inc.[2]
Standard Brands Incorporated
Standard Chemical Products, Inc.[2, 3, 4]
J. P. Stevens & Company, Inc.[1, 3, 4]

Tee-Pak, Inc.
Tennessee Eastman Company
Turner Hall Corporation

Union Carbide Chemicals Company[2, 4, 7]
United States Rubber Company[5, 7]

United States Testing Company[3]

Victor Chemical Works

Warner-Lambert Research Institute
The Wool Bureau, Inc.[1, 2]

FOOTNOTES

Project Participation and Fellowship Support
1. The Permanent Set and Supercontraction of Keratin Fibers
2. Fiber Surface Studies
3. Industry Cotton Research Project
4. The Resilience of Chemically Modified Cottons
5. Fatigue in Textile Fibers
6. The Chemical Reactivity of Cellulose and Cellulose Derivatives
7. Fellowship Donor

PERSONAL MEMBERS

HONORARY FELLOWS

William D. Appel
Frederic Bonnet
Herbert Hoover
Edward R. Schwarz
Hugh S. Taylor

LIFE

William D. Appel
A. G. Ashcroft
Lyman D. Briggs
Vannevar Bush
Donald Comer
Edward U. Condon
Donald H. Powers
Hugh S. Taylor
Rhett Y. Winters

INDIVIDUAL

Robert L. Amsler
Gregory Arapakis
Leslie Balassa
Herbert J. Ball
Clifford P. Bastuscheck
Jackson Bauer
John Baymiller
C. W. Bendigo
Eugene Bernat
Gerson J. Bernstein
Clark G. Berry
S. Martin Billett
John A. Bilton
Domenico Bosco
Marcel Bovyn
Hugh Monroe Brown
Robert H. Brown
H. T. Buckley
R. F. Caroselli
P. J. G. Carrothers
V. Lindsay Chase
Vincent Evart-Chmielnicki
Sanford L. Cluett
John B. Clark
Allan B. Clarke
E. H. Clayton
Eugene Cohn
Thomas D. Cole
Sherman Converse
Louis B. Cook
Jacques Corbiere
P. W. Cunliffe
J. Ellwood Currah
William F. Danner
W. G. Dicks
Helen Dikeman
Harold Wm. Dingee
Erb N. Ditton
Farouk H. Dossa
John H. Draper, Jr.
J. Dunkerly
Francois Ecochard
Sidney M. Edelstein
Rachel Edgar
Hugo Ehrhardt
J. P. Elting
Herman Epstein
W. D. Fales
Lucille Finley
Carole Flaherty
John Fox
Freeman W. Fraim
George M. Gantz
J. F. Gaunt
R. C. Geering
Robert L. Goldemberg
A. C. Goodings
J. F. Gschwind
Martin H. Gurley, Jr.
William H. Hagenbuch
J. B. Haglind
Emanuel Hatzopoulos
M. Earl Heard
Max R. Held
H. G. Hencken
Julian T. Hightower
Harold E. Hirsch
Joseph E. Hoesl
H. Hofmann
Giles E. Hopkins
David E. Howe
A. J. Huber
Cuthbert C. Hurd
J. L. Isenring
Thomas A. Jamieson
Albert E. Johnson
Louis R. Jones, Jr.
R. Jones
P. K. Kangle
Emil J. Kayser
S. J. Kennedy

Jacob Knup, Jr.
Maurice G. Kramer
Jules Labarthe
Lewis Larrick
Lawrence C. Leatherland
S. Clark Lilley
Louis F. Luechauer
Esther McCabe
S. B. MacFarlane
Pauline Beery Mack
W. C. MacMillan
G. D. Mallory
H. F. Mark
W. R. Marsden
John E. Masters
William C. Menzies, Jr.
R. E. Miskelly
C. J. Monego
Donald J. Montgomery
Leon E. Moody
Edwin Morgan
John S. Murray
Raymond P. Nordheim
Gordon Osborne
David E. Pearsall
Edward C. Pfeffer, Jr.
Raymond A. Pingree
J. J. Press
A. U. Priester, Jr.
Charles H. Reichardt
Malcolm J. Reider
Walter H. Ridley
Elliot Rosengarten
Karl T. Schaefer
Ralph G. Schaubhut
David C. Scott, Jr.
H. A. Secrist
Norman L. Seltzer
John R. Seydel
W. S. Shaw
Simon A. Simon
H. G. Simonds
Ralph B. Smith
Sidney G. Smith, Jr.
Harry C. Spatz
Donald H. Spitzli
Deane F. Stahmann
Richard B. Stehle
L. Stevens
William J. Stewart
Sabbat J. Strianse
H. Michael Strub, Jr.
Robert L. Stutz
George B. Suhrie
William F. Sullivan
Edward L. Taylor
Saul Tessler
M. Fred Thoma
Harold H. Tucker
W. F. Underwood
George A. Urlaub
Boris Uzenoff
Emery I. Valko
Gilbert F. Van Blarcom
Juan Villarroel L.
A. W. Vint
Kyle Ward, Jr.
Richard D. Wells
Herbert L. Werner
Eric Weyl
Howard J. White, Jr.
Ross Whitman
Joseph Wiebush
Melvin Wiener
John T. Wigington
P. J. Wood
W. S. Woodson, Jr.
Lawrence L. Wyss
W. M. Yow
George F. Zealand
William Zimmermann

ASSOCIATE

Norman C. Armitage
F. W. Bauer
Joseph H. Brant
Allan L. Brassell
William F. Brommelsiek
George S. Buck, Jr.
Alfred A. Burgeni
H. D. Corkum
Miles A. Dahlen
S. Jack Davis
John H. Dillon
Nicholas Drisch
Virginia L. Duncan
Joseph H. Dusenbury
Lyman E. Fourt
E. Friderici
Charles F. Goldthwait
Herbert C. Haller
Milton Harris
Robert M. Hoffman
G. H. Hotte
Julian S. Jacobs
Hayden B. Kline
John F. Krasny
Richard T. Kropf
Kermit S. LaFleur
G. K. Lake
Joseph B. Levy
R. Lindenfelser
Walter Lobunez
J. D. Long
W. James Lyons
John Menkart
David Milne
J. Fred Murray
Eugene Pacsu
Edgar J. Page
E. V. Painter
Charles S. Parsons
Russell W. Peterson
J. B. Quig
Ludwig Rebenfeld
H. B. Risher
Bruno R. Roberts
William J. Roberts
Stanley E. Ross
J. M. Salsbury
T. C. Sayers
Webster R. Schmidt
R. J. G. Schofield
Walter E. Scholer
Arthur G. Scroggie
Richard E. Seaman
W. Bailey Sellars
D. Shichman
L. S. Sinness
Leonard Smith
Leonard Soep
Harry E. Stanley
Richard O. Steele
E. W. Suppiger
F. H. Swezey
D. Bruce Thornton
Richard K. Toner
J. H. Trepganier
T. Vickerstaff
Werner von Bergen
Robert E. Wagner
Helmut Wakeham
James H. Wakelin
Harold J. Walter
Charles Weidmann
O. C. Wetmore
Howard J. White, Jr.
John C. Whitwell
Robert W. Work

STUDENT

Tchang Chung
S. Srikantiah
D. V. Muni Swamy
Bahram E. Yazdani

TRI PERSONNEL (as of December 31, 1960)

President John H. Dillon, Ph.D., F.T.I., physicist

RESEARCH AND EDUCATION

Associate Research Directors

Joseph H. Dusenbury, Ph.D., F.T.I., chemist
W. James Lyons, Ph.D., physicist
Ludwig Rebenfeld, Ph.D., F.T.I., chemist
Robert F. Schwenker, Jr., A.B., chemist

Research Associates

Walter J. Kauzmann, Ph.D., chemist
Eugene Pacsu, Ph.D., chemist
Donald H. Powers, Ph.D., chemist
Edward W. Suppiger, Ph.D., mechanical engineer
Hugh S. Taylor, K.B.E., D.Sc., LITT.D., LL.D., F.R.S., chemist
Arthur V. Tobolsky, Ph.D., chemist
John C. Whitwell, Ch.E., chemical engineer

Senior Scientists

Karin Beurling, M.S., chemist
Arthur B. Coe, B.S., microscopist
Cornelia Dansizer, B.S., chemist
Stanley C. Scheier, M.S., engineer
Stanley Weils, B.A., engineer

Junior Scientists and Research Assistants

Louis R. Beck, Jr., B.S.
Marna Garwood, B.A.
Edward B. Jeffries
Kay Morrison, B.S.
Agnes Revesz, B.S.
Marjie G. Scott, M.S.
Elizabeth C. Teulings, B.S.
Rudolph Turner, B.S.
Polly K. Way
Hong Wu, M.S.
Robert K. Zuccarello, A.A.

Research Fellows

V. D. Arendt
Gerald Bjorge
Thomas J. Cochrane, Jr.
George T. Davis
Elliot B. Grover
V. D. Gupta (postdoctoral)
P. J. Kangle (postdoctoral)
Donald D. Kasarda
Gerd N. La Mar
Leonard Lifland
John A. Regalbuto
Jonathan B. Rivlin
Henry Saffer
Robert P. Teulings

PUBLICATIONS DEPARTMENT

Richard K. Toner, Ph.D., Director of Publications
Dorothy D. Hollmann, A.B., Production Editor
Julian S. Jacobs, M.Sc., Consultant

ADMINISTRATIVE AND SERVICE DEPARTMENT

Paul C. Alford, Jr., Secretary-Treasurer
Bertha F. Golden, Administrative Assistant
Anne B. Mansfield, A.B., M.L.S., Librarian
Joan Umpleby, Accountant
Harold Lambert, Mechanician
Harry Buvel, Assistant Mechanician
Joshua Higgins, Storekeeper

Secretarial and Clerical

Noel Meyer
Christine Peakes
Helen Tornell
Elizabeth Vollrath
Eleanor Wills
Glenna Wood

Maintenance

Roy De Veto
William Burgher
Rubin Rodriguez

ADVISORY COMMITTEES

GENERAL RESEARCH

NORMAN C. ARMITAGE, *Chairman,* Vice President, Deering Milliken Research Corporation

EDWARD W. LAWRENCE, *Vice Chairman,* Director, Research & Development Laboratories, Cranston Print Works Company

WILLIAM S. BARNARD, Research Department, Chicopee Manufacturing Corporation

C. W. BENDIGO

JOSEPH H. BRANT, Director, Corporate Research, Colgate-Palmolive Company

R. H. BRAUNLICH, Research & Development Division, American Viscose Corporation

WALLACE R. BRODE

KENNETH V. CHACE, Technical Director, Berkshire Hathaway, Inc.

DAVID W. CHANEY, Executive Director, Chemstrand Research Center

J. L. DELANEY, General Superintendent, Joanna Cotton Mills

MASON DUPRÉ, JR., Assistant to Administrator, Agricultural Research Service, U. S. Department of Agriculture

T. WALLER GEORGE, Celanese Corporation of America

J. B. GOLDBERG, Technical Consultant to Textile and Allied Industries

L. AUBREY GOODSON, JR., Vice President & Director of Research, Dan River Mills Incorporated

CARL C. GORDON, Chief Chemist, Albany Felt Company

NORMAN S. GRACE, General Manager, Dunlop Research Centre

WALTER J. HAMBURGER, Director & Treasurer, Fabric Research Laboratories, Inc.

M. EARL HEARD, Vice President, Research, West Point Manufacturing Company

GILMAN S. HOOPER, Director, Research and Development, Fiber Development Department, Hercules Powder Company

DONALD F. HORNIG, Chairman, Department of Chemistry, Princeton University

HANS O. KAUFFMANN, Director, Inorganic Research and Development Department, Food Machinery & Chemical Corporation

RICHARD T. KROPF, Vice President and Director of Research, Belding Heminway Company, Inc.

G. K. LAKE, Director, New Products Development, Burlington Industries, Inc.

GERALD LAXER, Director of Science and Technology, The Wool Bureau, Inc.

R. S. LONG, Commercial Development Manager, Organic Chemicals Division, American Cyanamid Company

HERMAN MARK, Director, Polymer Research Institute, Polytechnic Institute of Brooklyn

FRED S. PERKERSON, Manager, Central Laboratory, Cone Mills Corporation

WILLIAM H. POISSON, Manager, Planning and Evaluation, Fiber Marketing Department, National Aniline Division, Allied Chemical Company

DONALD H. POWERS, Vice President, Toiletries & Cosmetics, Warner-Lambert Research Institute

E. W. RUGELEY, Senior Technical Advisor and Coordinator, Textile Fibers Division, Union Carbide Chemicals Company

HERBERT F. SCHIEFER, Chief, Textiles Section, Organic & Fibrous Materials Division, National Bureau of Standards

H. E. SCHROEDER, Assistant Director, Elastomer Chemicals Department, E. I. du Pont de Nemours & Co., Inc.

STUART H. SHERMAN, Development Manager, Textile Division, United States Rubber Company

ARTHUR L. SMITH, Technical Director, Chatham Manufacturing Company

RICHARD D. SMITH, Manager, Synthetic Fiber Development, The B. F. Goodrich Company

ARNOLD M. SOOKNE, Associate Director, Harris Research Laboratories, Inc.

PAUL B. STAM, Director of Research, J. P. Stevens & Company, Inc.

RICHARD O. STEELE, Research Laboratories, Rohm & Haas Company

REINER G. STOLL, Director, Application & Product Development, Celanese Fibers Company

JOHN M. SWANSON, Laboratory Director, Textile Research Laboratory, Textile Fibers Department, E. I. du Pont de Nemours & Co., Inc.

HUGH S. TAYLOR, President, Woodrow Wilson National Fellowship Foundation

N. B. TUCKER, Director, Research Division, Miami Valley Laboratories, The Procter & Gamble Company

WERNER VON BERGEN, Associate Director of Research, J. P. Stevens & Company, Inc.

HELMUT WAKEHAM, Director of Research and Development, Philip Morris Incorporated

RICHARD D. WELLS

JOHN WHARTON, Director of Research, Courtaulds (Alabama) Inc.

EDUCATION

MALCOLM E. CAMPBELL, *Chairman*
R. M. DRAKE, JR.
BERTRAND HAYWARD
DONALD F. HORNIG
MARTIN J. LYDON
J. G. MCNALLY
HERMAN MARK
LEONARD SMITH
HUGH S. TAYLOR
R. H. WILHELM

PUBLICATIONS

WALTER J. HAMBURGER, *Chairman*
HAROLD HEDBERG
ELMER HUTCHISSON
GERALD LAXER
C. H. MASLAND, 3RD

PATENTS

GEORGE FREMON, *Chairman*
NORMAN C. ARMITAGE
JOHN J. HANLON
ROBERT M. JONES
ALBERT SPERRY

THESIS RESEARCH OF PREDOCTORAL FELLOWS

Transport Across Liquid-Liquid and Liquid-Polymer Interfaces, THOMAS J. COCHRANE, JR., Advanced Graduate Student in Chemical Engineering (Courtaulds, Inc. Fellow). Advisor: Prof. Richard K. Wilhelm.

Dilatometric Studies on Interaction of Wool and Hair with Aqueous Solutions, DONALD D. KASARDA, Advanced Graduate Student in Physical Chemistry (U. S. Rubber Co. Foundation Fellow). Advisor: Prof. Walter J. Kauzmann.

6-Thio Derivatives of Cellulose and D-Glucose, LEONARD LIFLAND, Advanced Graduate Student in Organic Chemistry (The Camille and Henry Dreyfus Foundation Fellow). Advisor: Prof. Eugene Pacsu.

Transverse Deformation of Grillages, JOHN A. REGALBUTO, Advanced Graduate Student in Mechanical Engineering. Advisors: Prof. Edward W. Suppiger and Dr. John H. Dillon.

Physical-Chemical Studies on Dissolved Wool, HENRY W. SAFFER, Advanced Graduate Student in Physical Chemistry (Union Carbide Chemicals Co. Fellow). Advisor: Prof. Walter J. Kauzmann.

Fractionation of Polymers by Selective Adsorption, ROBERT P. TEULINGS, Advanced Graduate Student in Chemical Engineering. Advisor: Prof. John C. Whitwell.

Studies on Non-woven Fabrics, GERALD H. BJORGE; Second Year Graduate Student in Chemical Engineering (Johnson and Johnson Fellow). Advisors: Prof. John C. Whitwell and Dr. John H. Dillon.

Mechanical Engineering Studies of Textile Materials, ELLIOT B. GROVER, Second Year Graduate Student in Mechanical Engineering. Advisor: Prof. Edward W. Suppiger.

Cross-linking Reactions of Cellulose, VOLKER D. ARENDT, First Year Graduate Student in Organic Chemistry (Cone Mills Corporation Fellow). Advisor: Prof. Eugene Pacsu.

Studies in the Kinetics of Dyeing, GEORGE T. DAVIS, First Year Graduate Student in Physical Chemistry. Advisor: Prof. Hugh S. Taylor.

Structural Studies of Synthetic Fibrous Polymers, GERD N. LAMAR, First Year Graduate Student in Physical Chemistry (Celanese Corporation of America Fellow). Advisor: Prof. Arthur V. Tobolsky.

Studies of Alkali Metal Cellulosates, JONATHAN B. RIVLIN, First Year Graduate Student in Organic Chemistry. Advisor: Prof. Eugene Pacsu.

RESEARCH OF POSTDOCTORAL AND VISITING FELLOWS

Studies of Fiber Surface Characteristics, DR. ALDO BUSACCA, Postdoctoral Fellow in Physics. Advisor: Dr. W. James Lyons.

Molecular Weight Distribution Studies of Cellulose and Other Polymers by Selective Adsorption, DR. P. J. KANGLE, Postdoctoral Fellow in Organic Chemistry. Advisor: Prof. Eugene Pacsu.

X-ray Diffraction Studies of Fibrous Polymer Crystallization Phenomena, DR. V. D. GUPTA, Postdoctoral Fellow in Physics. Advisors: Prof. Arthur V. Tobolsky and Dr. John H. Dillon.

Nature of Free Hydroxyl Groups in Secondary Cellulose Acetate, MR. MAKOTO YANAKA, Visiting Fellow in Organic Chemistry. Advisor: DR. L. Rebenfeld.

SPONSORED PROJECTS

PROJECT ON PERMANENT SET AND SUPERCONTRACTION OF KERATIN FIBERS

Period of Support: 3 years ending November 30, 1962
Approximate Total Support Level: $93,000

J. H. Dusenbury, *Project Director*
Edward B. Jeffries
Marjie G. Scott
Cornelia Dansizer

Sponsors:
Albany Felt Company
Bachmann Uxbridge Worsted Company
The Barre Wool Combing Company Ltd.
Geo. W. Bollman & Co., Inc.
John H. Breck, Inc.
Burlington Industries, Inc.
Colgate-Palmolive Company
Deering Milliken Research Corporation
Harris Research Laboratories, Inc. (The Gillette Company)
Huyck Felt Corporation
Marriner & Co., Inc.
J. P. Stevens & Co., Inc.
The Wool Bureau, Inc. (International Wool Secretariat)

Objectives:

1. To investigate the physical and chemical mechanisms by which keratin fibers undergo permanent set and supercontraction.
2. To study the permanent set and supercontraction of keratin fibers which differ greatly in their cortical structures.
3. To study the effects of certain treatments, which cause permanent set and supercontraction in fibers, on the corresponding yarns and fabrics and to attempt to relate the fiber-assembly behavior to that of the constituent fibers.

IWS WOOL RESEARCH PROJECT

Period of Support: 2 years ending September 30, 1960
Total Support Level: $50,000

J. H. Dusenbury, *Project Director*
Cornelia Dansizer

Sponsor:
International Wool Secretariat (representing wool growers of Australia, New Zealand, and South Africa); technical cooperation by The Wool Bureau, Inc.

Objective:
To study the recovery of fibers and fabrics from extension and bending, under various ambient atmospheric conditions, as a function of chemical treatments, particularly internal polymer deposition and cross-linking.

PROJECT ON FATIGUE IN TEXTILE FIBERS

Period of Support: 2½ years ending April 30, 1961
Total Support Level: $87,000

W. James Lyons, *Project Director*
Kay Morrison
Stanley Wells

Sponsors:
Allied Chemical Corporation
American Cyanamid Company
American Viscose Corporation
Celanese Corporation of America
The Chemstrand Corporation
Sté. Chimiotex
Coats & Clark Inc.
Dunlop Research Centre
E. I. du Pont de Nemours & Co., Inc.
United States Rubber Company
Textile Division

Objectives:
1. To study the influence of static load, stress or strain amplitude, frequency, and other factors in the dynamic stressing of textile fibers on the deterioration in mechanical properties which is recognized as "fatigue".
2. To determine the elementary processes and structural changes, in fibers of representative, important types, that produce or contribute to mechanical fatigue.

PROJECT ON THE CHEMICAL REACTIVITY OF CELLULOSE AND CELLULOSE DERIVATIVES

Period of Support: 2 years ending February 28, 1961
Total Support Level: $32,000

Robert F. Schwenker, Jr., *Project Director*
Karin Beurling
Rudolph Turner

Sponsor:
The Kimberly-Clark Corporation

Objectives:
1. A basic study of the chemical reactivity of cellulose.
2. The formation of reactive cellulose intermediates.
3. The preparation and characterization of new cellulose derivatives.

PROJECT ON RESILIENCE OF CHEMICALLY MODIFIED COTTONS

Period of Support: 3 years ending November 30, 1961
Total Support Level: $135,000

J. H. Dusenbury, *Project Director*
Agnes Revesz
Elizabeth C. Teulings

Sponsors:

American Cyanamid Company
American Viscose Corporation
Burlington Industries, Inc.
Cone Mills Corporation
Deering Milliken Research Corporation
Foundation for Cotton Research and Education
M. Lowenstein & Sons, Inc.
Pepperell Manufacturing Company, Inc.
Quaker Chemical Products Corp.
Rohm & Haas Company
Standard Chemical Products, Inc.
J. P. Stevens & Co., Inc.
Union Carbide Chemicals Company, Div. of Union Carbide Corporation

Objectives:

1. To study chemical reactions leading to improved resilience in cotton, with particular attention to those reactions which produce clear-cut, quantitatively measurable chemical and physical changes within the fibers.
2. To study the relationships between the quantitative measures of these reactions and the physical and chemical properties of the treated fibers, with particular emphasis on the mechanical properties of the cotton fibers and fibrous assemblies.

INDUSTRY COTTON RESEARCH PROJECT

Period of Support: 5 years ending August 31, 1961
Total Support Level: $131,000

Ludwig Rebenfeld, *Project Director*
Polly K. Way

Sponsors:

The American Thread Company, Inc.
Coats & Clark Inc.
Cone Mills Corporation
Fabric Research Laboratories, Inc.
Joanna Cotton Mills Company
Johnson & Johnson
North Carolina State College, School of Textiles
Pepperell Manufacturing Company, Inc.
Riegel Textile Corporation
Standard Chemical Products, Inc.
J. P. Stevens & Company, Inc.
United States Testing Company

Objectives:

1. To determine the receptivity of the several strains and varities of cotton to chemical treatments and its relation to the chemical nature of cottons.
2. To determine the influence of selected fiber properties on processing characteristics and to determine the effect of processing on fiber properties.
3. To establish the influence of fiber characteristics on the processability of cotton by laboratory techniques.

PROJECT ON FIBER SURFACE STUDIES

Period of Support: 3 years ending August 31, 1963
Approximate Total Support Level: $91,350

W. James Lyons, *Project Director*
Stanley C. Scheier
Stanley Wells

Sponsors:
Albany Felt Company
Celanese Corporation of America
The Chemstrand Corporation
Cranston Print Works Company
Deering Milliken Research Corporation
E. I. du Pont de Nemours & Co., Inc.
National Cotton Council of America
Eugene W. K. Schwarz, Inc.
Standard Chemical Products, Inc.
Union Carbide Chemicals Company, Div. of Union Carbide Corporation
The Wool Bureau, Inc.

Objectives:

1. To characterize the surfaces of a wide variety of natural and synthetic fiber types with respect to geometric and frictional properties.
2. To explore the possible functional relationships among these surface properties, varying important parameters such as moisture content, finishes, molecular fine structure, swelling, and chemical modification.
3. To investigate the influence of fiber surface properties in processing operations such as drafting and spinning, as exhibited by the characteristics of fiber assemblies.

STUDY OF THE INDUSTRIAL POTENTIAL OF RADIOISOTOPIC METHODS IN THE TEXTILE INDUSTRY

Sponsor: U. S. Atomic Energy Commission
Period of Support: 1 year 3 mos. ending June 30, 1960
Total Support: $14,200
Chief Investigator: Ludwig Rebenfeld

RESILIENCE OF FIBERS

Sponsor: Office of Naval Research
Period of Support: 12 years ending May 31, 1962
Total Support: $194,600
Chief Investigator: John H. Dillon
V. D. Gupta
A. V. Tobolsky

MONOGRAPH ON IMPACT PHENOMENA IN TEXTILES

Sponsor: Quartermaster Research and Engineering Command, Department of the Army
Period of Support: 2 years 6 mos. ending March 29, 1961
Total Support: $24,874
Chief Investigator: W. James Lyons

FLAME-RESISTANT PARACHUTE PACK MATERIAL

Sponsor: Wright Air Development Division
Period of Support: approximately 14 months ending April 30, 1961
Total Support: $26,619
Chief Investigator: Robert F. Schwenker, Jr.
Robert K. Zuccarello

A SYSTEMATIC INVESTIGATION OF NONAQUEOUS SWELLING AGENTS FOR CELLULOSE TO PROVIDE NEW CHEMICAL AND PHYSICAL MODIFICATIONS OF COTTON

Sponsor: Agricultural Research Service, U. S. Department of Agriculture
Period of Support: 2 years ending June 19, 1962
Total Support: $46,805
Chief Investigator: Ludwig Rebenfeld
Hong Wu

THERMAL CHARACTERISTICS OF COATED TEXTILE FABRICS

Sponsor: U. S. Navy Supply Research and Development Facility, Clothing and Textile Division
Period of Support: 5 years ending June 30, 1961
Total Support: $88,005
Chief Investigator: Robert F. Schwenker, Jr.
Louis R. Beck, Jr.
Rudolph Turner

NOTES ON RESEARCH*

116. The Mechanical Properties of Hides and Single Collagen Fibers, William Virgin and James H. Wakelin, January.

117. Effect of Fiber Length on Cotton Fiber Properties, L. Rebenfeld, February.

118. The Spinning of Polymer-Blend Fibers Containing Polyacrylonitrile and Cellulose Acetate, Graham K. Morbey, J. C. Whitwell, and H. J. White, Jr., March.

119. Fiber Surface Analyzer, Part II, Aldo Busacca and W. James Lyons, April.

120. Rapid Methods for Determining the Nonfibrous Content of Cotton Fabrics, R. F. Schwenker, Jr., May-June.

*Available only to TRI Company Members.

121. Evaluation of Methods for Characterizing Fiber Crimp, W. James Lyons and J. H. Dusenbury, July-August.

122. Response of Cottons to Yarn Mercerization, L. Rebenfeld, September.

123. The Effects of Test Sequence and Fiber Tension in the Vibroscope Determination of Linear Density, W. James Lyons and J. H. Dusenbury, October.

124. Force-Extension Behavior of Man-Made Fibers in the Low-Extension Uncrimping Region, W. James Lyons and J. H. Dusenbury, November.

125. Response of Several Cottons to a Yarn Resin-Finishing Treatment, L. Rebenfeld, December.

PAPERS PUBLISHED

Technical Transformations in Textiles, John H. Dillon, *The Fourth Shift, 1960 Yearbook, Alabama Textile Manufacturers Association,* Montgomery, Alabama, 1960, p. 130-141.

Linear Thermal Expansion Coefficients for the Crystalline Phase in High Polymers, James H. Wakelin, Alison Sutherland, and Louis R. Beck, Jr., *J. Polymer Sci. 42,* 278-280 (January).

Mechanical Properties of Feather and Down Fibers. Part I: Measurements at 65% R.H. and 70°F, Joseph H. Dusenbury, Chang-Ning Wu, and Cornelia J. Dansizer, *Textile Research J. 30,* 277-290 (April).

Mechanical Properties of Feather and Down Fibers. Part II: Design and Operation of a Vacuum Vibroscope, Joseph H. Dusenbury, Chang-Ning Wu, and Cornelia J. Dansizer, *Textile Research J. 30,* 290-296 (April).

Some Theoretical Considerations of the Dyeing of Cellulose Acetate with Disperse Dyes, Howard J. White, Jr., *Textile Research J. 30,* 329-338 (May).

Effect of Fiber Length on Single Fiber Tensile and Resilience Properties, Ludwig Rebenfeld and Polly K. Way, *Textile Inds. 124,* 99-103 (July).

Load-Deflection Analysis of Fibers with Plane Crimp, Ricardo Chicurel and Edward W. Suppiger, *Textile Research J. 30,* 568-575 (August).

The Differential Thermal Analysis of Textile and other High Polymeric Materials (Letter), Robert F. Schwenker, Jr. and Louis R. Beck, Jr., *Textile Research J. 30,* 624-626 (August).

New Method of Removing Xanthate Groups from Carbohydrates. Chemical Structure of Methyl α-d-Glucopyranoside Monoxanthate, John J. Willard and Eugene Pacsu, *J. Am. Chem. Soc. 82,* 4347-4350 (August).

Location of Xanthate Groups in Viscose, John J. Willard and Eugene Pacsu, *J. Am. Chem. Soc. 82,* 4350-4352 (August).

An Experimental Study of Forced Vibration of Coplanar Curved Wires, William C. Hurt and Edward W. Suppiger, *Princeton University Mechanical Engineering Department Report* No. EM 1 (September).

Differential Thermal Analysis of Protein Fibers (Letter), Robert F. Schwenker, Jr. and Joseph H. Dusenbury, *Textile Research J. 30,* 800-801 (October).

Simplified Three-Dimensional Point Stress Analysis, William D. Freeston and Edward W. Suppiger, *Design News,* 126-127 (November).

Characterization of the Cortical Structures of Keratin Fibres by Urea-Bisulphite Solubility, Joseph H. Dusenbury, *J. Textile Inst. 51,* T756-T772 (December).

Effects of Fibre Diameter and Crimp on Properties of Wool Fabrics and other Fibre Assemblies. Part I. Introduction, John Menkart and Norman F. Roberts, *J. Textile Inst. 51,* T1438-T1442 (December).

Effects of Fibre Diameter and Crimp on Properties of Wool Fabrics and other Fibre Assemblies. Part II. Properties of Top, Roving, Yarn, and Fabric, Joseph H. Dusenbury and Cornelia J. Dansizer, *J. Textile Inst. 51,* T1443-T1460 (December).

A Tabular Collocation Method for Beam Vibration, Ricardo Chicurel and Edward W. Suppiger, *Trans. ASME,* Paper No. 60-WA-76 (December).

Studies of the Surface Geometry of Fibers. Part I: Preliminary Experiments, W. James Lyons, *Textile Research J. 30,* 955-958 (December).

PAPERS PRESENTED

Fundamental Considerations, presented by John C. Whitwell at the Seminars in the Physical Sciences, Trenton State College, Trenton, New Jersey, February 4.

Applications of Statistics, presented by John C. Whitwell at the Seminars in the Physical Sciences, Trenton State College, Trenton, New Jersey, February 11.

Designs Almost of Type B′, presented by John C. Whitwell before the American Society for Quality Control, New York City, February 27.

The Differential Thermal Analysis of Textile Materials, presented by Robert F. Schwenker, Jr. and Louis R. Beck, Jr. at the Spring Meeting of The Fiber Society, New Orleans, Louisiana, March 11.

Fiber Surface Roughness Studies, presented by Howard J. White, Jr. at the Textile Research Institute Annual Meeting, New York City, March 24.

Cellulose Xanthate Studies, presented by Eugene Pacsu at the Textile Research Institute Annual Meeting, New York City, March 24.

Differential Thermal Analysis, presented by Robert F. Schwenker, Jr. at the Textile Research Institute Annual Meeting, New York City, March 24.

Technical Transformations in Textiles, presented by John H. Dillon at the Annual Convention of the Alabama Textile Manufacturers Association, Biloxi, Mississippi, April 22.

A Critical History of Textile Research Institute, presented by John H. Dillon at a Press Conference for the Plastics Institute, New York City, April 26.

Statistics and Industrial Experimentation, presented by John C. Whitwell before the Princeton Area Science Education Committee, Princeton, May 10.

Recent Developments in Textiles, presented by John H. Dillon before the Rotary Club of Princeton, May 17.

Characterization of the Cortical Structures of Keratin Fibres by Urea-Bisulphite Solubility, presented by Joseph H. Dusenbury at The Second Quinquennial Wool Textile Research Conference, Harrogate, England, May 20.

Effects of Fibre Diameter and Crimp on Properties of Wool Fabrics and other Fibre Assemblies. Part I. Introduction, by John Menkart and Norman F. Roberts, presented by Joseph H. Dusenbury at The Second Quinquennial Wool Textile Research Conference, Harrogate, England, May 27.

Effects of Fibre Diameter and Crimp on Properties of Wool Fabrics and other Fibre Assemblies. Part II. Properties of Top, Roving, Yarn, and Fabric, presented by Joseph H. Dusenbury and Cornelia J. Dansizer at The Second Quinquennial Wool Textile Research Conference, Harrogate, England, May 27.

Effect of Length on Cotton Fiber Properties, presented by Ludwig Rebenfeld at the Cotton Research Clinic of the National Cotton Council of America, Asheville, North Carolina, May 31.

Where and Why Statistics? presented by John C. Whitwell at Union Carbide Plastics Company, Research Department, Bound Brook, New Jersey, June 15.

Effect of Cotton Fiber Structure on Response to Chemical Treatments, presented by Ludwig Rebenfeld at the Gordon Research Conference on Textiles, American Association for the Advancement of Science, New London, New Hampshire, July 14.

The Fundamentals of Factorials, presented by John C. Whitwell at the Twelfth Annual Rutgers Conference on Quality Control, New Brunswick, New Jersey, September 10.

Dependence of Cotton Fiber Properties on Fiber Structure, presented by Ludwig Rebenfeld at the 138th Meeting, American Chemical Society, New York City, September 14.

Differential Thermal Analysis of Cellulose and Certain Cellulose Derivatives, presented by Robert F. Schwenker, Jr., Louis R. Beck, Jr., and Eugene Pacsu at the 138th Meeting, American Chemical Society, New York City, September 15.

X-ray Angle of Cotton and Response to Chemical Finishing, presented by Ludwig Rebenfeld at the Chemical Finishing Conference of the National Cotton Council of America, Washington, D.C., September 28.

Introductory Remarks, Panel Discussion on Wool Research, presented by John H. Dillon at the Annual Fall Meeting of the National Association of Wool Manufacturers, Absecon, New Jersey, October 11.

Discussion of T.R.I. Wool Research, Panel Discussion on Wool Research; presented by Joseph H. Dusenbury at the Annual Fall Meeting of the National Association of Wool Manufacturers, Absecon, New Jersey, October 11.

Preparation and Characterization of Sodium Cellulosates, presented by Robert F. Schwenker, Jr., Tetsuo Kinoshita, Karin Beurling and Eugene Pacsu at the Third Cellulose Research Conference, Cellulose Research Institute, Syracuse, New York, October 27.

DOCTORAL THESES

An Analysis and Interpretation of Polymer Stress Relaxation Data, Richard E. Heitman, Department of Chemical Engineering, Princeton University, May, 1959. Thesis Advisor: Prof. John C. Whitwell.

A Multivariable Study of Mixed Polymer Spinning, Graham Morbey, Department of Chemical Engineering, Princeton University, June, 1960. Thesis Advisor: Prof. John C. Whitwell.

Dynamic Analysis of Coplanar Crimped Elastic Filaments, William Denney Freeston, Jr., Department of Mechanical Engineering, Princeton University, September, 1960. Thesis Advisor: Prof. Edward W. Suppiger.

PATENTS

After-glow Suppressing Cellulose Derivatives, Eugene Pacsu and Robert F. Schwenker, Jr., Canadian Patent 609638 (November 29).

TRI SEMINARS

Textile Properties—Customer vs. Consumer Interests, Jules Labarthe, Carnegie Institute of Technology, January 7.

Capillary Sorption Phenomena in Fiber Bodies, Alfred A. Burgeni, Personal Products Corporation, January 21.

Rheological Properties of Hydrogen-Bonded Solids, Alfred H. Nissan, Rensselaer Polytechnic Institute, March 3.

Elastic Properties of Swollen Cellulose Gels, J. J. Hermans, Cellulose Research Institute, March 17.

Significance of Wool Fiber Properties, J. H. Dusenbury, Textile Research Institute, March 31.

Mass Transfer between Phases, Thomas J. Cochrane, Jr., Textile Research Institute, April 21.

Influence of Chemical Structure on Polymer Physical Properties, S. A. Sundet, E. I. du Pont de Nemours & Company, Inc., May 12.

Wash-and-Wear Wool Fabrics, John F. Krasny, Harris Research Laboratories, May 26.

Unidentified Sulfur Compounds in Wool Hydrolysates, A. Robson, Wool Industries Research Association, September 23.

Volume Changes Accompanying Acid-Base Reactions of Protein Fibers, D. D. Kasarda, Textile Research Institute, October 20.

Mechanism of Deformation in Polyamide Fibers, William F. McDevit, E. I. du Pont de Nemours & Company, Inc., November 10.

Configurational Set and Recovery of Some Textile Yarns and Fibers, J. L. Riley, Celanese Corporation of America, November 17.

Acrylic Fiber Structure and Properties as a Function of the Coagulation System, A. B. Craig and J. P. Knudsen, Chemstrand Research Center, Inc., December 8.

STAFF PROFESSIONAL ACTIVITIES

John H. Dillon, Vice-President, The Fiber Society; Member, Board of Trustees, The Philadelphia College of Textiles and Science; Editorial Board, Journal of Applied Polymer Science; Member, Advisory Panel to the Organic and Fibrous Materials Division of the National Bureau of Standards, National Academy of Sciences; Member, American Panel, The Textile Institute; Member, Executive Committee, Society of Rheology; Member, Advisory Board, Office of Critical Tables, National Academy of Sciences.

Joseph H. Dusenbury, Chairman, 1959-1960, and National Council Representative, 1960-1961, New Jersey Chapter, American Institute of Chemists.

W. James Lyons, Member, Executive Committee, and Secretary-Treasurer, Division of High-Polymer Physics, American Physical Society.

Ludwig Rebenfeld, Member, Awards Committee, The Fiber Society.

Robert F. Schwenker, Jr., Secretary-Treasurer, Princeton Area Science Education Committee.

Arthur B. Coe, Treasurer, Polymer and Fiber Microscopy Society.

PROGRAM—1960 ANNUAL MEETING

THURSDAY AND FRIDAY, MARCH 24 AND 25, 1960

Opening Remarks, LEONARD SMITH, Director of Utilization Research, National Cotton Council of America, Chairman, TRI 30th Annual Meeting

TRI Research in 1959
Introduction, J. H. DILLON, President
Fiber Surface Roughness Studies, H. J. WHITE, JR., Director of Research
Cellulose Xanthate Studies, EUGENE PACSU, Research Associate
Differential Thermal Analysis, ROBERT F. SCHWENKER, JR., Group Leader

Reversible Crimp in an Acrylic Fiber
R. B. TAYLOR, R. L. TICHENOR, J. F. RYAN and E. M. HICKS, JR., E. I. du Pont de Nemours & Co., Inc., Presented by E. M. HICKS, JR., "Orlon" Technical Director, Textile Fibers Dept.

The Enigma of Liquid Space, An Address by THE HONORABLE JAMES H. WAKELIN, The Assistant Secretary of the Navy, Research and Development

S.M. 27, A Man-Made High Modulus Cellulosic Fiber, GEOFFREY V. LUND and J. WHARTON, Courtaulds (Alabama) Inc. Presented by GEOFFREY V. LUND, Director, Textile Research and Development

Crease Recovery and Wash-Wear Behavior in Cellulosic Fabrics, Presented by RICHARD STEELE, Head, Textile Research Laboratory, Rohm and Haas Co.

Principles of Non-Woven Fabrics, STANLEY BACKER, Associate Professor of Mechanical Engineering, Textile Division, Massachusetts Institute of Technology, and DE WITT R. PETTERSON, Research Engineer, Chicopee Manufacturing Corporation. Presented by STANLEY BACKER

Some Developments in Wool Textile Research in Australia, Presented by M. LIPSON, Chief, Division of Textile Industry, Wool Research Laboratories, C.S.I.R.O., Geelong, Australia

Recent Improvements in Textile Processing Machinery and Methods, Presented by RALPH A. RUSCA, Head, Machinery Development Investigations, Southern Utilization Research and Development Division, Agricultural Research Service, USDA

Joint Report on the Institute, WILLIAM E. CLARK, Vice President and General Manager, Textile Division, United States Rubber Company, Chairman of the Board, Textile Research Institute, and J. H. DILLON, President

The Structure and Properties of Arnel 60, A New Triacetate Staple Fiber, Presented by B. SHELDON SPRAGUE, Head, Fiber Physics and Evaluation Research Section, Summit Research Laboratories, Celanese Corporation of America

Recent Developments in Polyvinyl Alcohol Fibers, RICHARD D. WELLS, Manager, Fiber Department, Air Reduction Chemical Co. and HENRY M. MORGAN, Assistant Director, Fabric Research Laboratories, Inc. Presented by RICHARD D. WELLS

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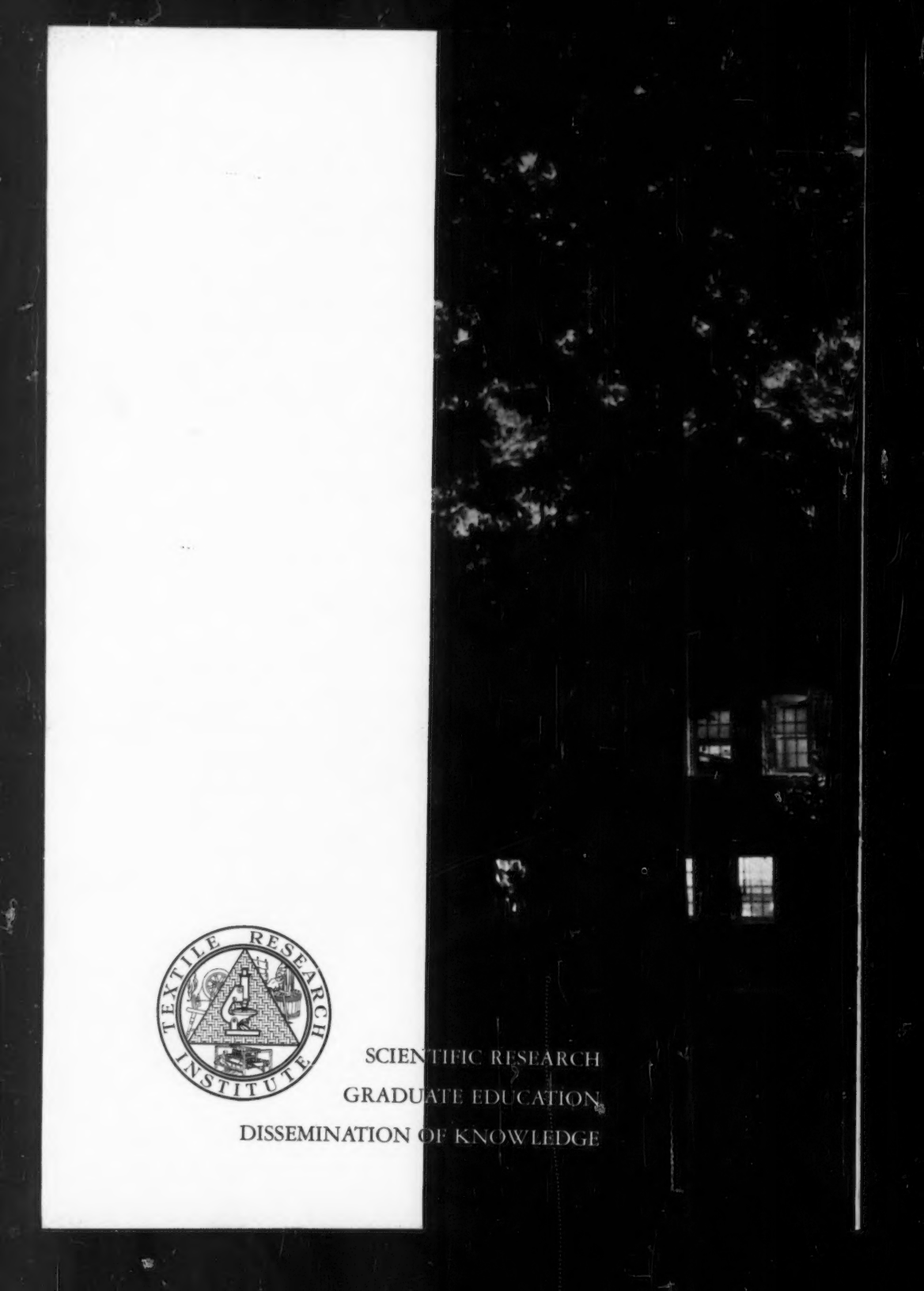

SCIENTIFIC RESEARCH

GRADUATE EDUCATION

DISSEMINATION OF KNOWLEDGE